WINTER HABITAT SELECTION BY BLACK-TAILED DEER ON VANCOUVER ISLAND: A JOB COMPLETION REPORT

# INTEGRATED WILDLIFE INTENSIVE FORESTRY RESEARCH

*A cooperative project between the Ministry of Environment and Parks and the Ministry of Forests and Lands*

# WINTER HABITAT SELECTION BY BLACK-TAILED DEER ON VANCOUVER ISLAND: A JOB COMPLETION REPORT

R.S. McNay and D.D. Doyle

July 1987

This Publication is IWIFR-34

B.C. Ministry of Forests and Lands, Research Branch EP 923
B.C. Ministry of Environment and Parks, Wildlife Bulletin B-53

This project is jointly funded and directed by the
B.C. Ministries of Environment and Parks and Forests and Lands

Copies of this report may be obtained, depending on supply, from:

Research Branch
B.C. Ministry of Forests and Lands
1450 Government Street
Victoria, B.C.
V8W 3E7

Wildlife Branch
B.C. Ministry of Environment and Parks
Parliament Buildings
Victoria, B.C.
V8V 2X5

The contents of this report may not be cited in whole or in part without the approval of the Director of Research, B.C. Ministry of Forests and Lands, Victoria.

Citation:

McNay, R.S. and D.D. Doyle. 1987. Winter habitat selection by black-tailed deer on Vancouver Island: a job completion report. Research, B.C. Ministry of Environment and Parks and B.C. Ministry of Forests and Lands. IWIFR-34. Victoria, B.C.

## ABSTRACT

The results of a 5-year study concerning the selection of winter habitat by black-tailed deer are reported. Comparisons are made between 10- to 40-year-old pole-sapling stands and $300^{+}$-year-old old-growth forests as to their relative merits as winter habitat. A total of 28 radio-collared deer were located over 5 years to categorize seasonal movement strategies and winter habitat selection. Three seasonal movement behavioural types were recognized: obligate migrators, facultative migrators, and non-migratory residents. Resident deer comprised half the sample, while three deer made obligatory migrations. Seasonal movement strategies varied between deer, but fidelity to particular behaviours and seasonal range locations was strong. Seasonal home ranges of migratory deer were significantly larger than those of resident deer. Deer tended to use all habitat types located within their respective home ranges. However, excluding early successional habitats ( $<10$ years old), most migratory deer used all forest types and most resident deer used only pole-sapling habitats. The habitat use that was recorded through weekly monitoring was adopted as a descriptor of habitat availability: if an animal used a particular area that area was assumed to be available to the animal under normal circumstances.

Habitat use during specific winter weather conditions was compared to the available habitats determined from weekly locations. A total of 75 individual animal-sessions were recorded from eight separate intensive monitoring periods. Results indicated that seasonal movement behaviours of deer and specific weather events influenced observed patterns of habitat selection. Cold temperatures and/or snow generally reduced home range size and forced deer to seek the closest forested habitat. Wind increased home range size and again restricted use to forested habitats. Home range sizes became more variable and most deer tended to prefer early successional habitats during mild weather. Most deer reduced their mobility during periods of snow accumulation (13-40% reduction in the distance moved between successive 2-hourly locations).

In dealing with inclement weather during winter, the radio-collared deer used a host of different strategies. The strategies seem to be adopted at an early age and maintained by the individual throughout its life. The long-term success of any of these strategies is unknown, especially during severe winters.

## ACKNOWLEDGEMENTS

We would like to express gratitude to the many people who have been associated with the Integrated Wildlife - Intensive Forestry Research group. All the participants of that group have helped in most phases of our research, from initial research direction to final report production. The Wildlife Section of the B.C. Ministry of Environment and Parks (Region 1) contributed additional technical support and a wealth of accumulated knowledge concerning black-tailed deer wintering habits on Vancouver Island.

MacMillan Bloedel Ltd., through the co-operation of B. Cafferata, are to be thanked for their interest and support of the project. The University of British Columbia, through the leadership of F. Bunnell, contributed academic stimulation and technical support.

A few people (M. Chutter, L. Giguere, V. Heinsalu, B. Mason, R. Page, and L. Peterson) gave more support to the project than was requested and in so doing have contributed quality and significance to our work.

R. Roberge and R. Page adapted analysis programs to the IBM personal computer and F. Bunnell, R. Davies, T. Hamilton, D. Janz, I. McDougall, G. Montgomery, B. Nyberg, J. Peek, L. Peterson, J. Schoen, and J. Yeo reviewed the document.

The project was co-operatively funded and administered by the B.C. Ministry of Environment and Parks, the B.C. Ministry of Forests and Lands, and the University of British Columbia.

TABLE OF CONTENTS


ABSTRACT ..... iii
ACKNOWLEDGEMENTS ..... iv

1 INTRODUCTION ..... 1
1.1 Rationale and Objectives ..... 1
1.2 Study Area ..... 3
1.3 Climate ..... 5
1.4 Deer Population ..... 8

2 SEASONAL MOVEMENTS AND WINTER HABITAT SELECTION BY BLACK-TAILED DEER ..... 8
2.1 Methods ..... 11
2.2 Results ..... 14
2.2.1 Sample conditions ..... 14
2.2.2 Seasonal movement patterns ..... 20
2.2.3 Home range sizes ..... 20
2.2.4 Winter habitat use ..... 24
2.3 Discussion ..... 29

3 HABITAT PREFERENCE BY BLACK-TAILED DEER DURING SPECIFIC WINTER WEATHER EVENTS ..... 35
3.1 Methods ..... 36
3.2 Results ..... 39
3.2.1 Sample conditions ..... 39
3.2.2 Centres of activity ..... 39
3.2.3 Home range sizes ..... 42
3.2.4 Habitat use ..... 42
3.2.5 Mobility ..... 46
3.3 Discussion ..... 48

4 SUMMARY AND CONCLUSIONS ..... 53

5 LITERATURE CITED ..... 57

## APPENDICES


1 Immobilization of black-tailed deer ..... 62

2 Summary of telemetry samples and status of radio-collared deer ..... 66

3 A comparison of pellet group sampling and radio telemetry as measures of habitat use by deer ..... 67

4 Winter diet determination from rumen and fecal analyses ..... 71

5 Fecal nitrogen and 2,6 diaminopimelic acid profiles in old-growth and pole-sapling winter habitats of black-tailed deer ..... 79

6 Activity patterns of deer during specific winter weather events ..... 86


## TABLES


1 Summary of deer harvest records for the South Nanaimo River Camp ..... 10

2 Mean seasonal home range sizes and distance between seasonal home range centres ..... 25

3 Mean home range sizes and distances between activity centres (intensive monitoring) ..... 43

4 Deer mobility index during mild and cold-snowy weather ..... 49


## FIGURES


1 Location of the South Nanaimo River Camp study area ..... 4

2 Successional stage mosaic created by forest harvesting and fire ..... 6

3 An index of winter severity on Vancouver Island from 1890-1986 .. 7

4 Deer population index trends for the South Nanaimo River Camp ... 9

5 Deer population response to wolf control in the South Nanaimo River Camp ..... 15

6 Snow accumulation, maximum and minimum temperatures (3-day intervals), and 3-day maximum of the daily average windspeed ..... 17

7 Winter weather severity index trends ..... 18

8 Data summary for deer locations (weekly telemetry) ..... 19

9 Spatial distribution of radio-collared deer and their seasonal home range locations ..... 21

10 Distance between winter and summer home range centres of individual deer ..... 22

11 Site fidelity to seasonal home ranges ..... 23

12 The distribution of home range sizes used by radio-collared deer ..... 26

13 Habitat use by radio-collared deer during winter ..... 27

14 Habitat types that compose the study area and that were used by radio-collared deer ..... 28

15 Elevation and aspect use by radio-collared deer ..... 30

16 Data summary for deer locations (intensive monitoring) ..... 40

17 Three-hourly maximum and minimum temperatures and daily average windspeed traces for each of the eight intensive monitoring periods ..... 41

18 Activity centres for radio-collared deer during warm, cold-snowy, or windy weather ..... 44

19 Habitat use by radio-collared deer (intensive monitoring) ..... 45

20 Proportional use of habitats during mild and cold-snowy weather conditions ..... 47

# 1 INTRODUCTION

## 1.1 Rationale and Objectives

A conflict between managing the deer and forest resources on Vancouver Island was described in two reports by the Strategic Studies Branch of the British Columbia Ministry of Forests (McDaniels Research Ltd. 1980 and B.C. Ministry of Forests and Ministry of Environment 1982). The problem centred around the competing demand for old-growth forests as both deer winter habitat and a rich source of wood fibre for use by the lumber industry. Both resources offer great economic and social welfare to the people of British Columbia. The timber industry generated $66 million in gross stumpage alone in the Vancouver Forest Region in 1984-85 (B.C. Ministry of Forests 1985), while black-tailed deer are worth $5.. million per year in total revenue from hunting (Reid 1985a, b) and probably the same amount in non-consumptive use (Reid et al. 1985). Black-tailed deer are the third most sought after big game species in the province (176 600 hunter days in 1985), and occur on less than 17% of the land base. Within the coastal region of British Columbia deer receive 93% of the total hunter days allocated to all big game species (calculated from Reid 1985a, b).

Generally there are two concerns over the management of the deer resource on Vancouver Island (McNay and Davies 1985). First, predation on deer by wolves is a short-term management problem being currently addressed by the B.C. Ministry of Environment and Parks (B.C. MOEP). This concern has stimulated research projects on northern Vancouver Island to determine the effects of wolves on deer productivity and recruitment (Hatter 1982, 1983; Atkinson and Janz 1986), and has led to efforts to manage wolf populations (Janz and Hatter 1986). Second, the longer-term deer management problem originates from a conflict in objectives between the B.C. MOEP and the managers of the forest resource -- that is the B.C. Ministry of Forest and Lands (B.C. MOFL) and the forest companies (Robinson 1956). Intensive forest management has the potential to cause large scale changes to deer habitat structure and quality, but wildlife managers have limited influence on where and when the changes occur.

With 28.5 million $m^3$ of timber being harvested annually in coastal British Columbia (6-year average from 1978-79 to 1983-84) -- which can represent 35 000 ha/yr in the Vancouver Forest Region alone (B.C. Ministry of Forests 1984) -- deer habitat biologists began to voice a concern for the future supply of deer habitat. The carrying capacity of winter habitats throughout North America is thought to be sensitive to changes caused by intensive forestry practices, particularly when coupled with the occurence of severe winter weather (Edwards 1956; Klein and Olson 1960; Potvin et al. 1981; Saver and Severinghaus 1983). Because of excessive mortality of deer recorded during severe winters on mid-Vancouver Island (Smith 1969) and on northern Vancouver Island (Jones and Mason 1983), the conflict in British Columbia has centred around winter habitat management specifically (Nyberg et al. 1986). The IWIFR program was created, in part, to address the issue of winter habitat management. Detailed problem analyses were developed by McNay and Davies (1985) and Nyberg (1985), and this report summarizes the 5 years of field research that has been conducted (Nyberg et al. 1985). This report specifically deals with the portion of the research that has been called the "deer project". The deer project complements other IWIFR projects reported elsewhere. For example, the overall objective of the IWIFR "habitat project" (Nyberg 1985) is to investigate the effects of intensive forestry on those elements relevant to deer and elk habitat quality.

The overall objective of the IWIFR deer project was to assess the selection and use of winter habitat by Columbian black-tailed deer (Odocoileus hemionus columbianus) to determine:

i. the key features of winter habitats preferred by deer, and
ii. the reactions of deer to changes in those features.

Specific objectives were to:

i. develop live capture techniques for collaring deer with radio transmitters (Appendices 1 and 2);
ii. compare pellet group counts and radio telemetry as alternative means of determining habitat use by deer (Appendix 3);

iii. determine seasonal movements and winter habitat use patterns exhibited by radio-collared deer (Section 2);

iv. monitor deer intensively during specific winter weather events as a means of identifying habitat preference (Section 3, Appendices 4-6);

v. sample preferred habitats for food and snow characteristics as a means for assessing winter habitat quality;[1] and

vi. construct a conceptual model for the assessment of habitat quality for deer (McNay et al. 1987).

Research began during December 1981, with field work being initiated concurrently with project planning. Field study continued primarily during the winter months of November through March, until March 1986. The 5th and last year of field work coincided with the writing of completion reports and planning for the second phase (1987-1991) of the IWIFR program.

## 1.2 Study Area

The study was conducted in the area of the southernmost tributary of the Nanaimo River on Vancouver Island. That area is locally known as the South Fork or the South Nanaimo River Camp and is situated 20 km southwest of Nanaimo, B.C. (Fig. 1). The study area encompasses approximately 225 $km^2$ of which 111 $km^2$ were studied intensively. The terrain is mountainous with steep U-shaped valleys arranged in an east to west orientation. Elevation ranges from 305 m at the valley bottom to 1400 m. The land is privately owned by MacMillan Bloedel Ltd. (Cowichan Woodlands Division) and is incorporated under their taxation Tree Farm #19. The South Fork portion of this logging division is also the water supply watershed for the city of Nanaimo.

---

[1] Page, R. and R.S. McNay. [1987]. Deer use of food and snow: a comparison of sampling techniques. B.C. Min. For. Lands, Res. Branch, Victoria, B.C. In preparation.

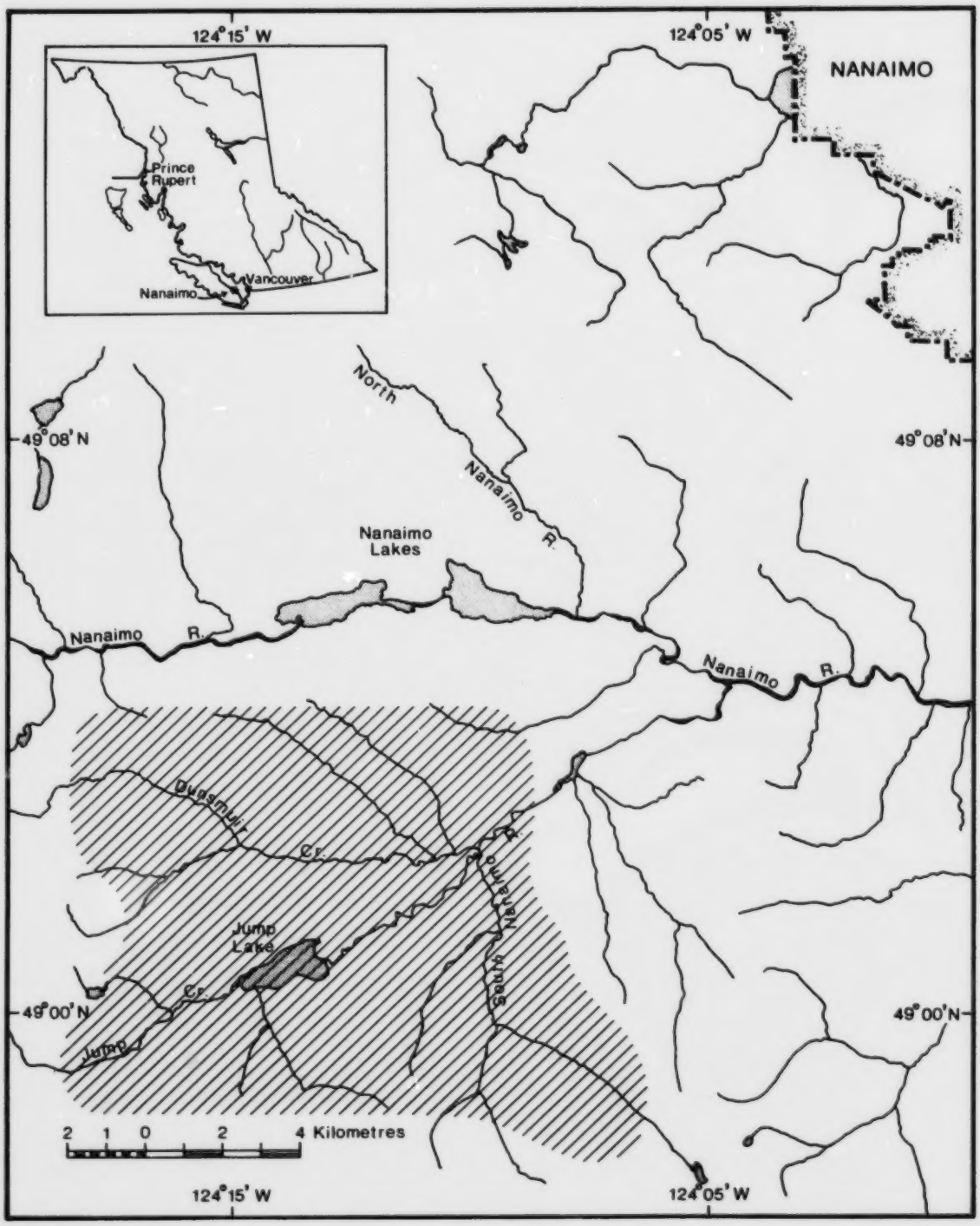


FIGURE 1. Location of the South Nanaimo River Camp study area.

Most of the intensively studied area occurs within the Coastal Western Hemlock Biogeoclimatic Zone (sensu Klinka et al. 1984), with a small portion in the Subalpine Mountain Hemlock Zone. Approximately 25% of the area is in the wetter subzone, Leeward Montane Maritime variant (CWHb4) and is dominated by western hemlock (Tsuga heterophylla) and amabilis fir (Abies amabilis). The remainder is in the drier Maritime Subzone, Vancouver Island variant (CWHa1) and is dominated by Douglas-fir (Pseudotsuga menziesii) with some western hemlock and western redcedar (Thuja plicata).

Although logging was widespread when it first started in the South Nanaimo River Camp in the late 1940's, current logging activities are limited to the periphery of the main study area. The logging has created a mosaic of successional stages, with recent clearcuts (i.e., early successional stages less than 10 years old) representing 44% of the area, and most of the remaining area evenly divided between 10- to 40-year-old pole-sapling forests (23%) and isolated stands of old-growth timber (23%). Approximately 7% of the main study area was burned during 1965 and 1966, which has resulted in stands of mixed pole-sapling and old-growth trees (Fig. 2). Restocking of the harvested area has been primarily with Douglas-fir. A thinning program has been implemented on some pole-sapling stands to reduce stem density.

## 1.3 Climate

Because the focus of research was to be placed on deer winter habitat, it was important to understand snowfall patterns in south coastal British Columbia. An analysis of long-term Atmospheric Environment Service records (data on file, Atmospheric Environment Service, Ottawa, Ontario) revealed that extreme snowfalls on Vancouver Island tend to occur at 18-year intervals and that snowfalls follow cyclical trends in the intervening years (Fig. 3).[2]

---

[2] Page, R. 1987. Eighteen-year cycles in Vancouver Island snowfall. B.C. Min. For. Lands, Res. Branch, Victoria, B.C. Unpublished memorandum.

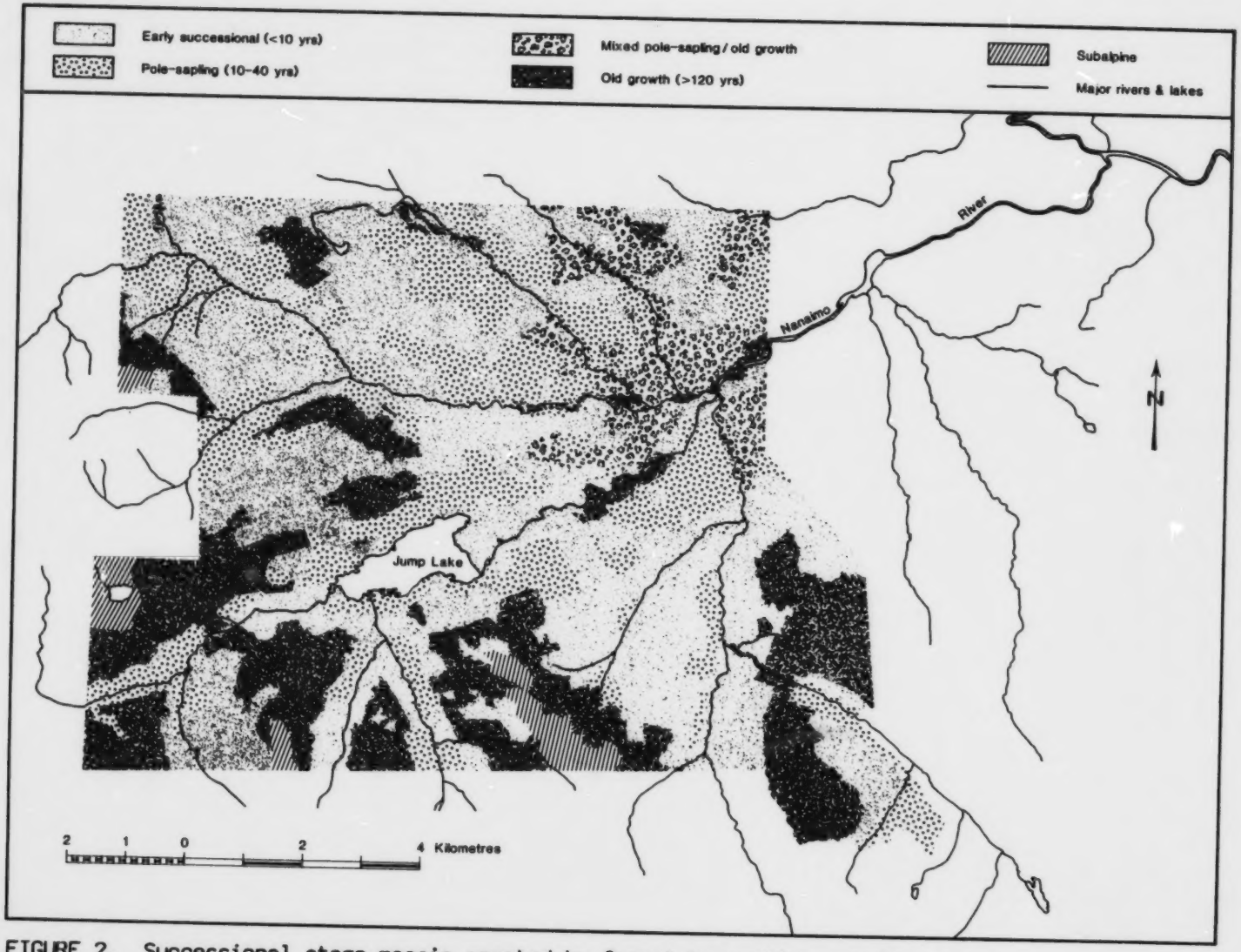


FIGURE 2. Successional stage mosaic created by forest harvesting and fire.

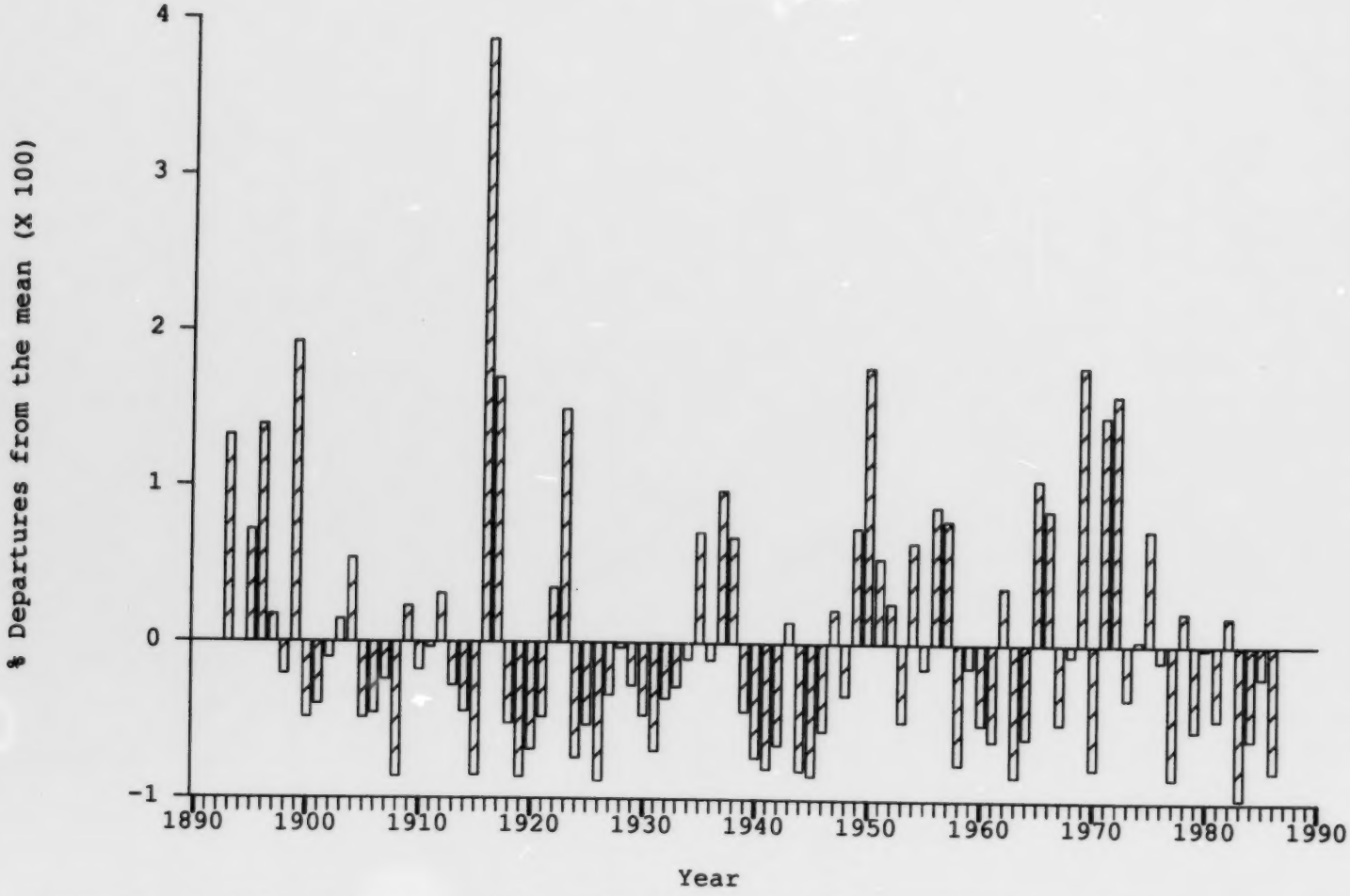


FIGURE 3. An index of winter severity on Vancouver Island from 1890-1986. The index is expressed as the departure from the mean annual snowfall calculated from data collected at four snow measurement stations (Victoria, Courtenay, Nanaimo/Nanaimo airport, Port Hardy) on Vancouver Island from 1890 to 1986 (analysis of data from Atmospheric Environment Service, Ottawa, Ont.).

It is not surprising that Robinson (1956) expressed concern for winter habitat following the series of relatively severe winters during the early to mid-1950's and that Jones (1975) repeated the same concern following the series of relatively severe winters during the late 1960's and early 1970's (Fig. 3). By comparison, this study was conducted during a period of relatively mild winter weather insofar as Vancouver Island annual snowfall is concerned.

### 1.4 Deer Population

In 1977, annual counts of black-tailed deer were initiated using spotlights at night to survey standard roadside transects through areas recently clearcut. Since then the highest population index (no. deer per kilometre of transect) for the watershed as a whole has been 19 deer per kilometre in 1979 (average of sub-watersheds; Fig. 4). A minimum population estimate from the age structure of harvest data indicated that the summer population was 2500 in 1979.[3] The study area was being managed as a "trophy bucks area" during the course of the study and a summary of harvest data from gate access records, along with the yearly hunting regulations, is presented in Table 1.

## 2 SEASONAL MOVEMENTS AND WINTER HABITAT SELECTION BY BLACK-TAILED DEER

The recent investigation of the winter ecology of Vancouver Island black-tailed deer began with Jones (1974,1975), and continued with Stevenson (1978), Harestad (1979), and Rochelle (1980). The results of these studies, as well as others summarized by Bunnell and Jones (1984) and Bunnell (1985), identified old-growth forest as important winter habitat for deer during periods of snow accumulation. The lower snowpacks and greater forage abundance (mainly arboreal lichens as litterfall) made old-growth habitats energetically superior winter habitats compared to recent clearcuts (less than

---

[3] Smith, G.W., J.A. Youds, H.D. Langin, and D.M. Hebert. 1979. Nanaimo River and Nanaimo Lakes plan. B.C. Min. Environ., Wildl. Branch, Nanaimo, B.C. 23 p.

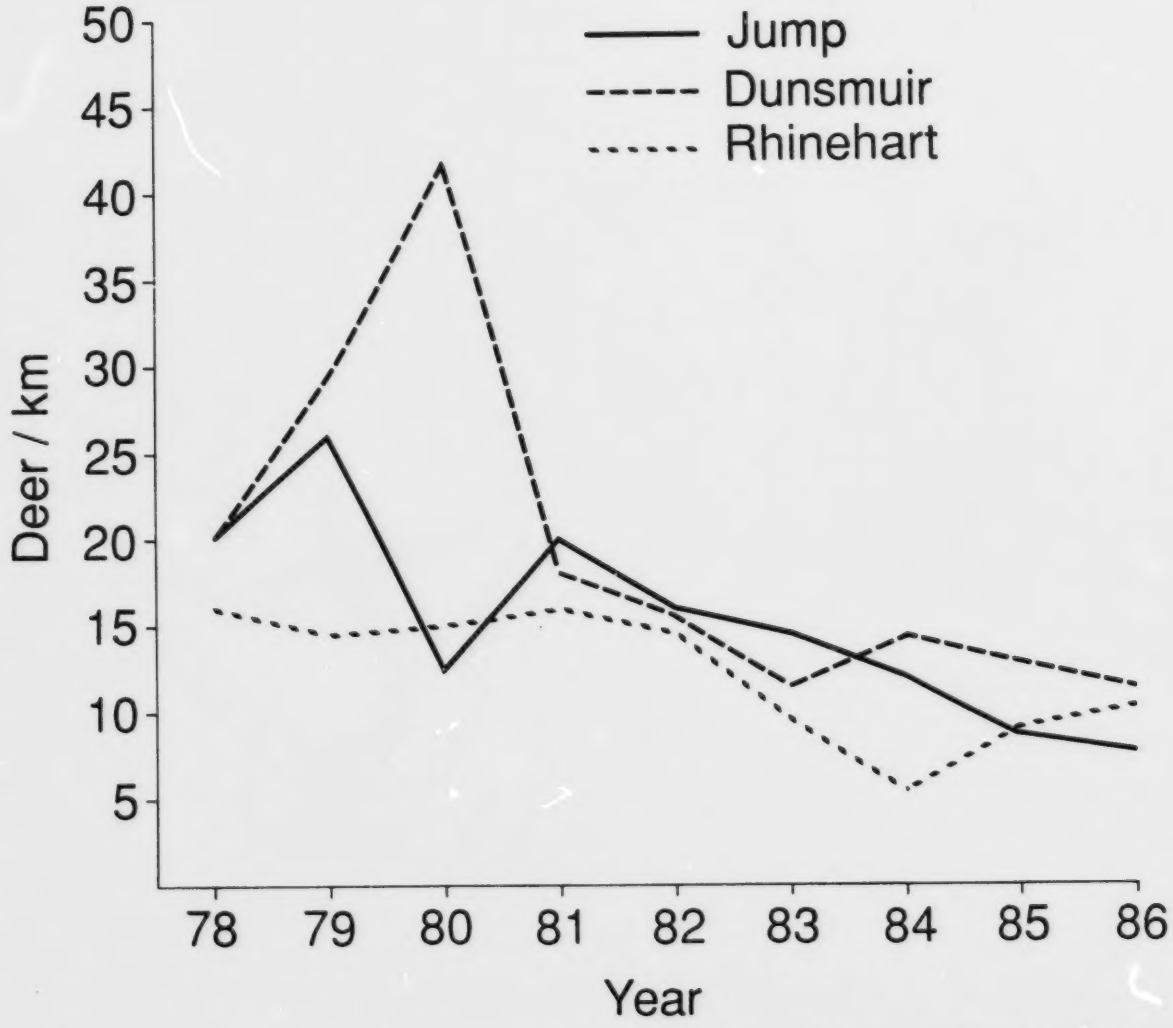


FIGURE 4. Deer population index trends for the South Nanaimo River Camp (Jump, Dunsmuir and Rhinehart are subdrainages of the main watershed).

TABLE 1. Summary of deer harvest records[a] for the South Nanaimo River Camp

| Year | Number of hunter days | Antlered | Antlerless | Total | Hunter[b] success |
|---|---|---|---|---|---|
| 1956 | 791 | 73 | 19 | 92 | 11.6 |
| 1960 | 1504 | | | 202 | 13.4 |
| 1961 | 1551 | 133 | 126 | 259 | 16.7 |
| 1962 | - | NO RECORDS | | - | - |
| 1963 | 1577 | 154 | 150 | 304 | 19.3 |
| 1964 | 1176 | 142 | 117 | 259 | 22.0 |
| 1965 | 1178 | 65 | 88 | 153 | 13.0 |
| 1966 | 1527 | 104 | 69 | 173 | 11.3 |
| 1967 | 1267 | 80 | 62 | 142 | 11.7 |
| 1968 | 924 | 98 | 50 | 148 | 16.0 |
| 1969 | 713 | 24 | 29 | 53 | 7.4 |
| 1970 | 714 | 74 | 34 | 108 | 15.1 |
| 1971 | 684 | 46 | | 46 | 6.7 |
| 1972 | 514 | 38 | | 38 | 7.4 |
| 1973 | 522 | 51 | | 51 | 9.8 |
| 1974 | 935 | 48 | | 48 | 5.1 |
| 1975 | 1422 | 88 | | 88 | 6.2 |
| 1976 | - | NO RECORDS | | - | - |
| 1977 | 2561 | 126 | | 126 | 4.9 |
| 1978 | 2897 | 116 | | 116 | 4.0 |
| 1979 | 2957 | 120 | | 120 | 4.1 |
| 1980 | 2513 | 94 | 30 | 124 | 4.9 |
| 1981 | 3726 | 186 | 17 | 203 | 5.4 |
| 1982 | 3101 | 80 | 25 | 105 | 3.4 |
| 1983 | 2743 | 97 | 34 | 131 | 4.8 |
| 1984 | 2722 | 81 | 27 | 118 | 4.3 |
| 1985 | 2217 | 56 | 25 | 81 | 3.7 |

[a] Summary of hunting regulations

| | |
|---|---|
| 1956: | 1 Antlerless bag limit, bag limit 3 |
| 1957-70: | 2 Antlerless bag limit |
| 1971-73: | Bucks only |
| 1974-79: | Antlered only: 2 pts. or better |
| 1980: | Antlered: 3 pts. or better |
| | Limited Entry Hunting - 50 spike buck permits |
| | - 75 antlerless permits |
| 1981: | Antlered: 2 pts. or better |
| | Limited Entry Hunting - 50 spike buck permits |
| | - 75 antlerless permits |
| 1982-85: | Antlered: 2 pts. or better |
| | Limited Entry Hunting - 50 spike buck permits |
| | - 100 antlerless permits |

[b] Hunter success = total harvest/number of hunter days.

10 years old). The lack of older second-growth stands (20-50 years old) in earlier studies precluded any investigations of seasonal use or habitat selection of these stands compared to old-growth stands. Our general objectives were to investigate seasonal movements and winter habitat selection in an area with 15- to 40-year-old pole-sapling and 300$^{+}$-year-old old-growth stands, and to increase the data base through larger sample sizes than were possible for previous research on Vancouver Island deer. This data base could then be used to identify deer by seasonal movement behavioural types and to define habitat type availability for further investigations of winter habitat preference (see Section 3).

## 2.1 Methods

Radio transmitters (Telonics, Inc., Mesa, Ariz.) were placed on deer captured in or near previously identified winter habitats (typically old-growth stands located on south-facing slopes between 300 and 900 m in elevation [Nyberg et al. 1986]). Because of neck swelling in male deer during the rut and associated problems with expanding collars (Telonics, pers. comm., June 1982), only female deer were radio collared. Deer were captured live for radio collaring by Clover trapping (Clover 1956) or chemical immobilization with succinylcoline chloride (Anectine) in 6-10 mg Pneu darts (Pneu Dart, Inc., Williamsport, Pa.) fired from a Palmer Capchur gun. Darting of deer was accomplished either by stalking them on foot or by spotlighting them from a vehicle at night. Survival and cause-specific mortality rates for the radio-collared animals were calculated using "MICROMORT" (Heisey and Fuller 1985).

Animal location was derived by two different methods. For the first 3 years, triangulation was employed, using three to five bearings from known locations identifiable on 1:20 000 base maps. The animals' location was interpreted as the centre of the resulting polygon (Hupp and Ratti 1983). Using the degree of intersection of the bearings, a precision estimate of the location was derived similar to the techniques used by Harestad (1979) and modified according to Janz et al. (1980). Along with animal location, recorded in Universal Transverse Mercator (UTM) grid

coordinates, a precision estimate, date, time, estimates of weather conditions at the time of location (temperature, wind speed, cloud cover, precipitation, and snow depth), and habitat age class (after Janz et al. 1980) were recorded. In the final year, a computer-assisted approach was used.[4] The latter approach used the error angle associated with each bearing to construct an error polygon (defined as that area of overlap from bearings with a 95% probability of being true). The centroid of the error polygon was used as the animals' location. Recording of other data at the time of location was similar to the triangulation method, with the addition of the observer's estimate of the error angle associated with each bearing (5 or 8°). Telemetred deer locations were sampled on a weekly basis in the winter (November through March) and biweekly at other times of the year. Additional visual sightings were included in the data set.

The data were stratified by eliminating location points collected more frequently than every 3 days to achieve a less biased weighting of any 1 week. This was necessary as visual sightings tended to be grouped during other phases of work.

Seasonal home ranges were described by using 100, 90, and 50% of the weekly deer locations sampled during one season and the minimum convex polygon areas were calculated using the home range program called "HOME" (Harestad 1981). Stratification of seasons for most deer was categorical (summer was defined as April through October and winter was defined as November through March). Seasons for deer that migrated depended upon their movement dates. Seasonal home ranges did not include migration routes. Distances between seasonal home ranges within years (summer to winter) and among years (summer to summer and winter to winter) were derived from the harmonic mean centres of home ranges from the program "CENTRE" (Harestad 1981). Both CENTRE and HOME were adapted for use on an IBM personal computer. Differences in home range size between seasons, years, and behavioural types were investigated by using analysis of

---

[4] Page, R. [1987]. Computer analysis of radio-telemetry data in the field. J. Wildl. Manage. (submitted) 17 p.

variance in association with Duncan's multiple range test (SAS Institute Inc. 1985). A simple procedure was also used to test the quality of the seasonal home range size estimates. If the rate of change of home range size, calculated in a chronological sequence using the last 10 radio locations, was less than 10% eight of nine times, then it was considered to be asymptotic and therefore representative of the true home range size for that season.

Aspect and elevation classes were derived from a 1:20 000 scale contour map of the study area (see Fig. 16). Successional stages (early successional, pole-sapling, mixed pole-sapling/old growth, and old growth) were derived from an ecosystematic association map (Clements 1985). Habitat types, for the purposes of this report, were assumed to be synonymous with successional stage classification. Habitat and elevation/aspect use by deer were determined by plotting animal locations on individual mylar sheets at 1:20 000 scale and overlaying the plots on the appropriate map sheet to classify individual locations. Error in the overlay method was negligible because animal location plots and habitat maps had identical computer-generated UTM grids. Locations that fell on habitat borders were split, giving each habitat half of a location.

Weather data specific to the study location were recorded using a battery operated CR-21 weather data logger (Campbell Scientific Canada Inc., Edmonton, Alta.). The weather station was placed at 600 m elevation in an early successional habitat on a southern aspect. Data collected included hourly maximum and minimum temperature and average hourly wind speed. Snow depths were recorded after each snowfall and three times weekly whenever snow accumulations lasted longer than 3 days.

Temperature, wind, and snow data were summarized every week during the winter period. Temperature, wind speed, and snow depth were grouped into classes of measurements (after Leckenby and Adams 1986) with each class being weighted relative to the stress on deer. (For details see Leckenby and Adams 1986.) The resulting indices of weekly air temperature, air movement, snow cover, and snow depth were summed to

determine a winter severity index for the week. These weekly data were then plotted to obtain graphical representation of the winter severity index patterns that existed during the study.

## 2.2 Results

### 2.2.1 Sample conditions

We radio-collared 36 deer, 28 of which lived for longer than 12 months following capture (Appendix 2). Details and comparative efficiencies of capture techniques are provided in Appendix 1. Survival of radio-collared deer (all adult does) over the length of the study was estimated to be 30%. Wolf predation was the highest single mortality factor, estimated at 27% over the length of the study. It was apparent by April 1982 that wolves (Canis lupus) were a serious confounding factor in the study area, both in terms of killing radio-collared animals and in altering deer behaviour. As the influence of wolves could not be measured, and because maintaining radio collars on specific animals for long time periods was important, wolf control was initiated in December 1982. A total of 35 wolves were killed in the study area by March 1986. The removal led to a decrease in annual adult doe mortality rates by wolves from 23%, recorded in the pre-removal year, to a post-removal average of 4% per year. Following wolf control, juvenile recruitment rates in spring counts and fawn/doe ratios in August counts (Fig. 5) showed a positive response. The deer per kilometer index however, does not show as marked a response. The problems associated with transect selection for night counts is likely the main cause. As the vegetation along night count transects regenerated to the point at which visibility was obstructed, they were replaced with more recent clearcuts in the general vicinity. The lack of recent logging activity in the study area (for new transects) and the dropping of certain transects due to visibility constraints confounded the deer per kilometre index calculation.

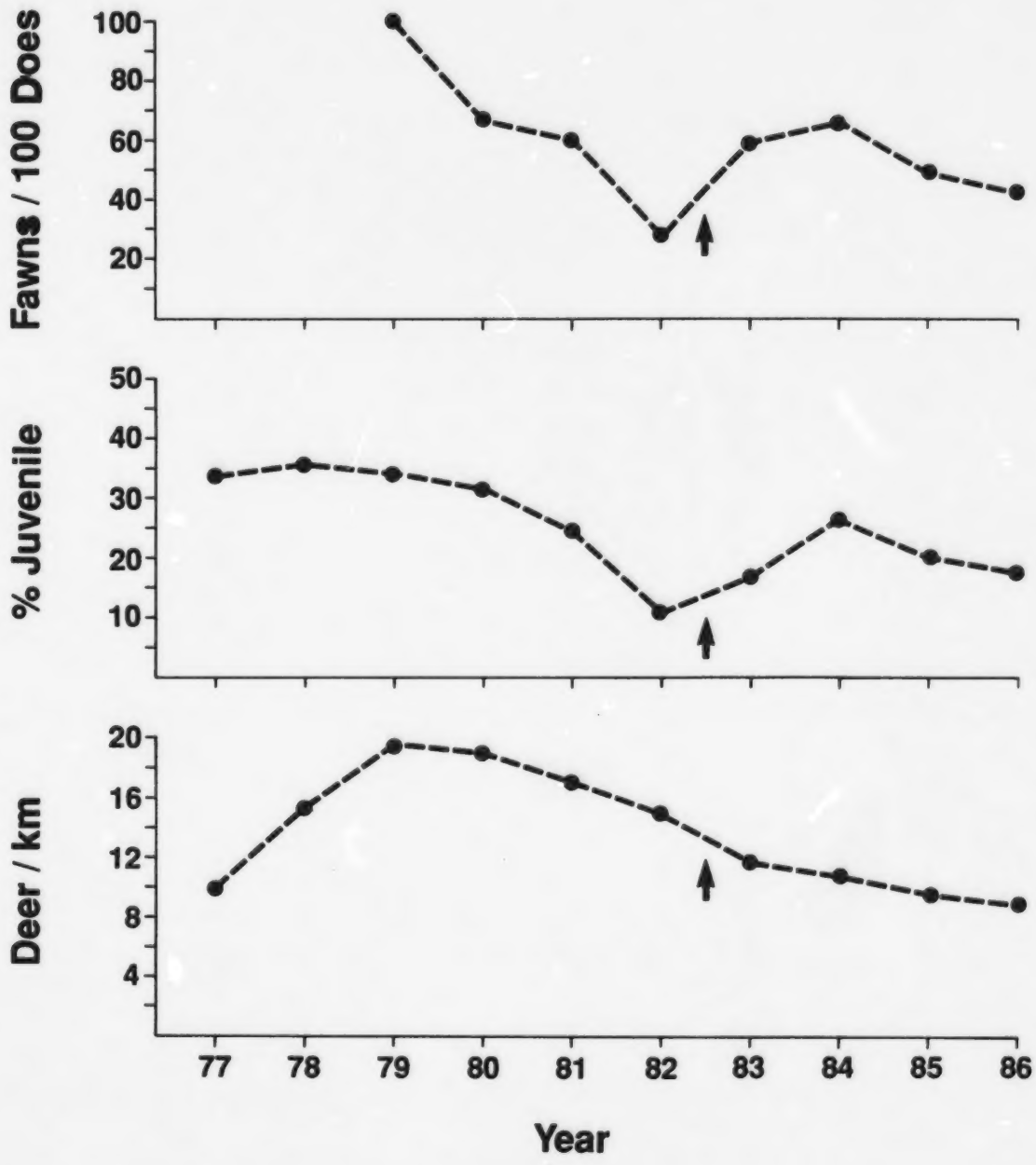


FIGURE 5. Deer population response to wolf control in the South Nanaimo River Camp. (Arrow indicates the year that wolf control was initiated.)

No cougar (Felix concolor) were removed as problem animals by B.C. MOEP officials nor were harvested by hunters. Predation by cougars was considered to be a lower risk than predation by wolves, given the historic mortality patterns. Cougar predation on radio-collared deer was 1.26% per year throughout the study.

The winters of 1982-83 through 1985-86 were mild over Vancouver Island (Fig. 3) and in the study area there was only an ephemeral snowpack at lower elevations. Only during the last 2 years did snowpacks accumulate to depths that could have a direct effect on habitat selection (Fig. 6). Since the duration of these packs was never greater than 20 days, the overall severity of the winters to deer was probably insignificant. We used the severity index calculation presented by Leckenby and Adams (1986) to compare our estimate of winter severity to others reported in the literature. Only during three short intervals over the 5-year study did the winter severity reach a level that could be considered to be critical for deer (Fig. 7). During December 1983, for approximately 1 week the severity index fell to below -500, primarily because of high winds in combination with low temperatures. During February 1985, a high snow accumulation and cold temperatures pushed winter severity to below -800, but only for approximately 2 weeks. Again in February of the next year, snow and cold temperatures lasting about 1 week caused serious weather conditions for deer. A total winter severity index was not computed (i.e., summation of weekly winter severity indices) because of the incomplete nature of the data; therefore, no direct comparisons can be made to the winters sampled by Leckenby and Adams (1986). A visual comparison of Figure 7 with the similar plots of Leckenby and Adams (1986) indicates an absence of both high and moderate annual winter severity throughout our study.

A total of 2710 weekly deer locations, representing 140 deer seasons (Fig. 8) were recorded during the study. Most locations (76%) were taken between 0800 and 1600 hr. Forty-seven percent of locations taken during winter months occurred with no snow

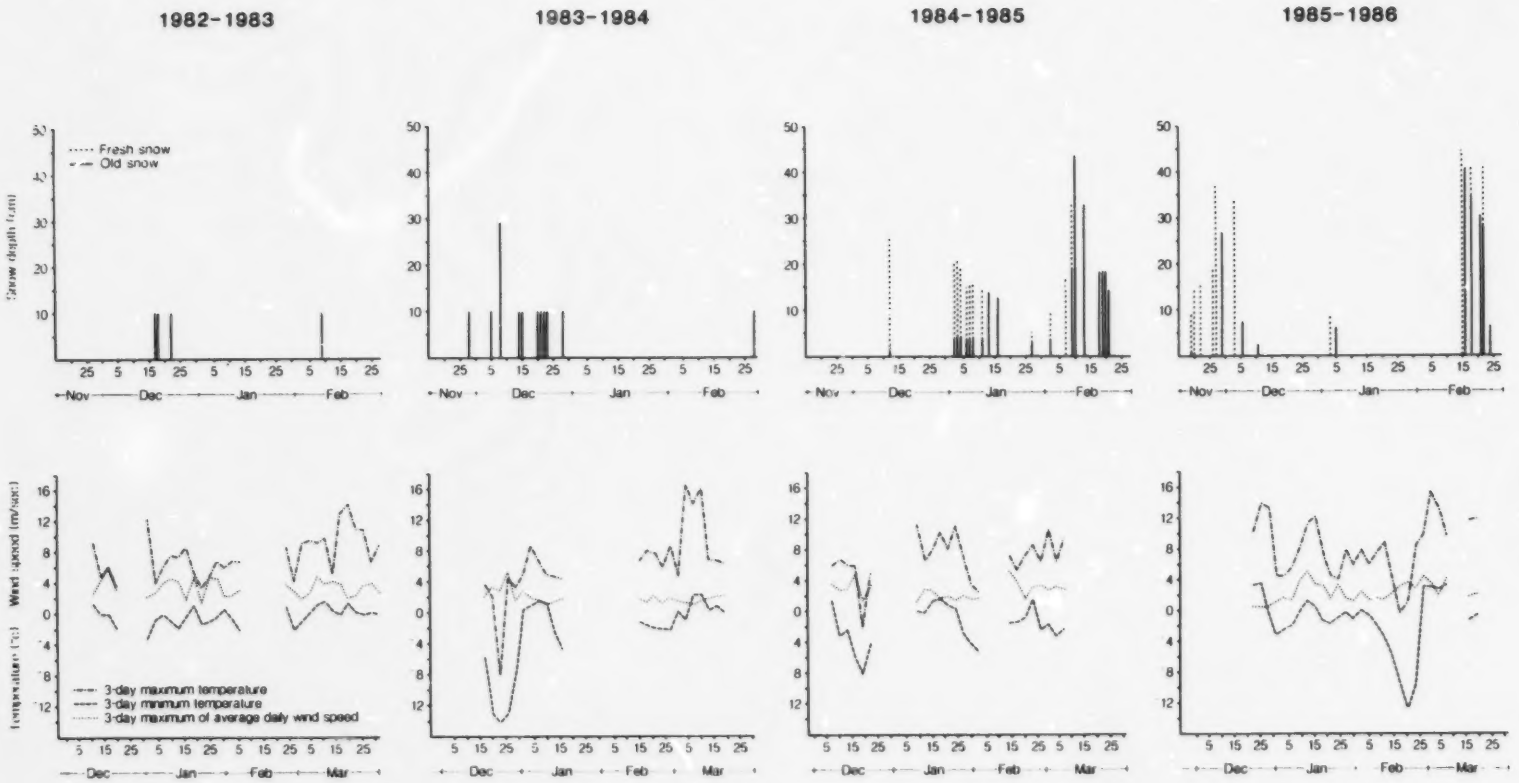


FIGURE 6. Snow accumulation, maximum and minimum temperatures (3-day intervals), and 3-day maximum of the daily average windspeed.

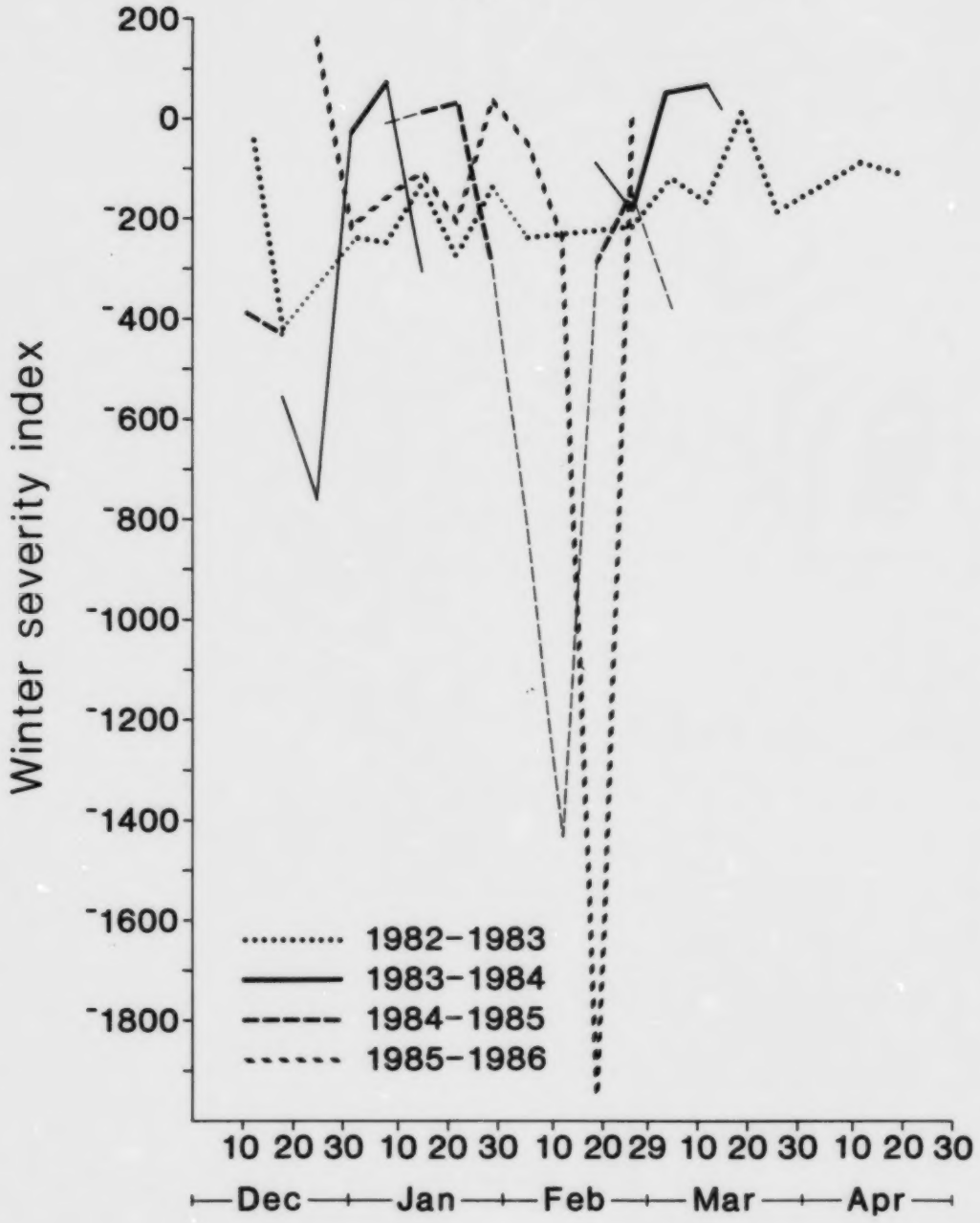


FIGURE 7. Winter weather severity index trends (after Leckenby and Adams 1986). Lightweight lines indicate that the weekly winter severity calculation was estimated using 5 or 6 days of data rather than 7.

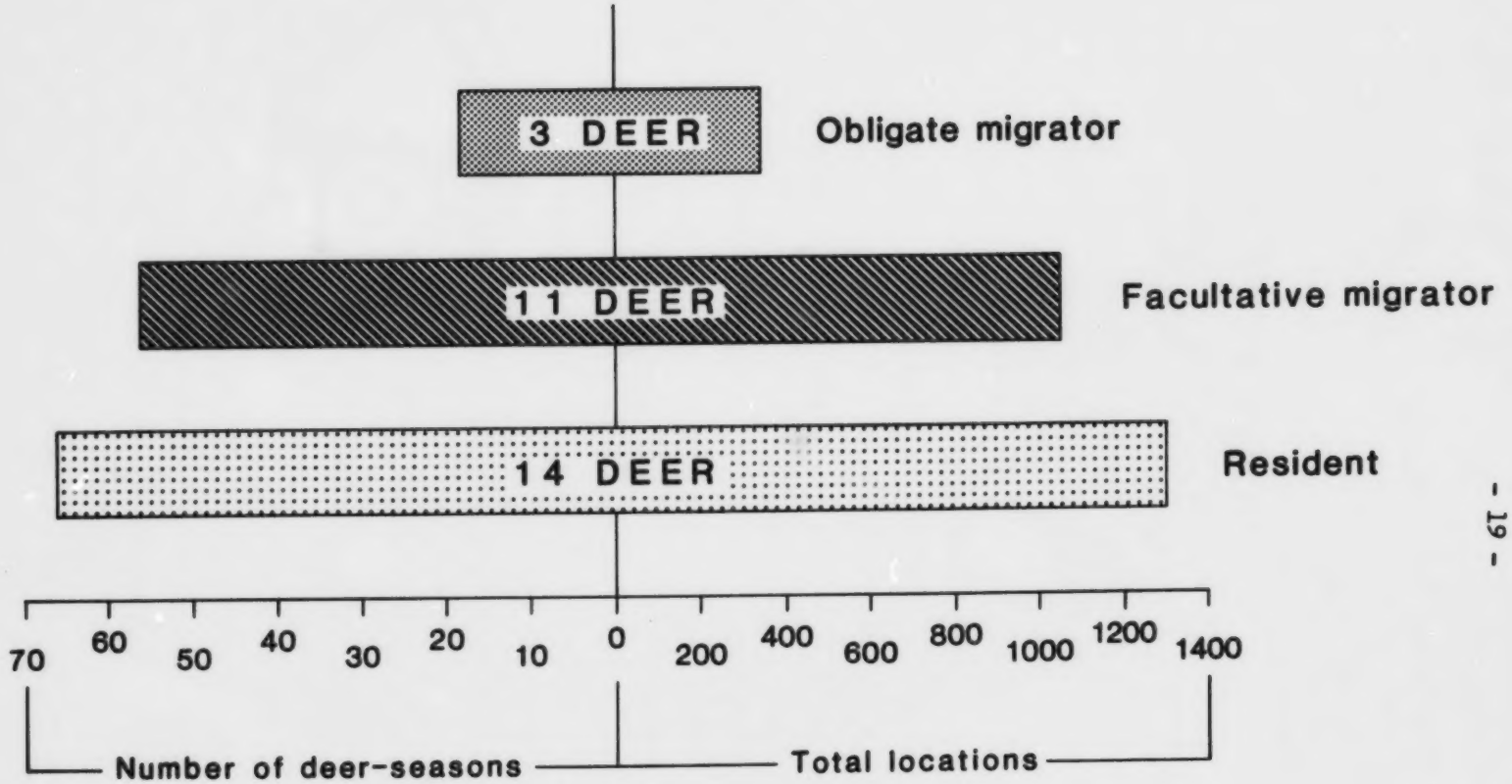


FIGURE 8. Data summary for deer locations (weekly telemetry).

accumulation and only 20% of the winter locations were taken at temperatures below 0°C.

2.2.2 Seasonal movement patterns

Deer seasonal movement behavioural types were identified during periods of snow accumulation. Obligate migrators were defined as those deer that moved between seasonal home ranges irrespective of snow accumulation. The timing of migrations varied between individuals but remained consistent ($\leq$ 2-3 weeks variation) from year to year. Facultative migrators moved in a pattern that tended to follow cycles of snow accumulation and ablation. With one exception, resident deer made no significant movements ($<$ .8 km). Figure 9 illustrates the spatial distribution of the radio-collared deer and their seasonal home range locations. The distances moved between seasonal home ranges varied from less than 400 m for most resident deer to 1-13 km for migratory deer (Fig. 10).

Although there was variation in the distance between winter and summer home range centres, the radio-collared deer exhibited strong individual site fidelity within seasons (Fig. 11). Facultative migrators showed the greatest variation in winter centres, which was to be expected given the variable winter conditions experienced during the study. Only one deer (obligate migrator No. 79) showed a significant change (8.4-8.8 km) in her winter home range centre, but it was a change in duration of time spent on a seasonal range rather than a change in actual location. There was little change in summer home range centres for any of the behavioural types.

2.2.3 Home range sizes

When the data set was stratified by deer, behavioural type, year, and season (winter and summer), analysis of variance and Duncan's multiple range test revealed no significant differences in home range size. However, only 34% of the seasonal data sets met our asymptote criterion. When years were pooled, 96% of the seasonal home

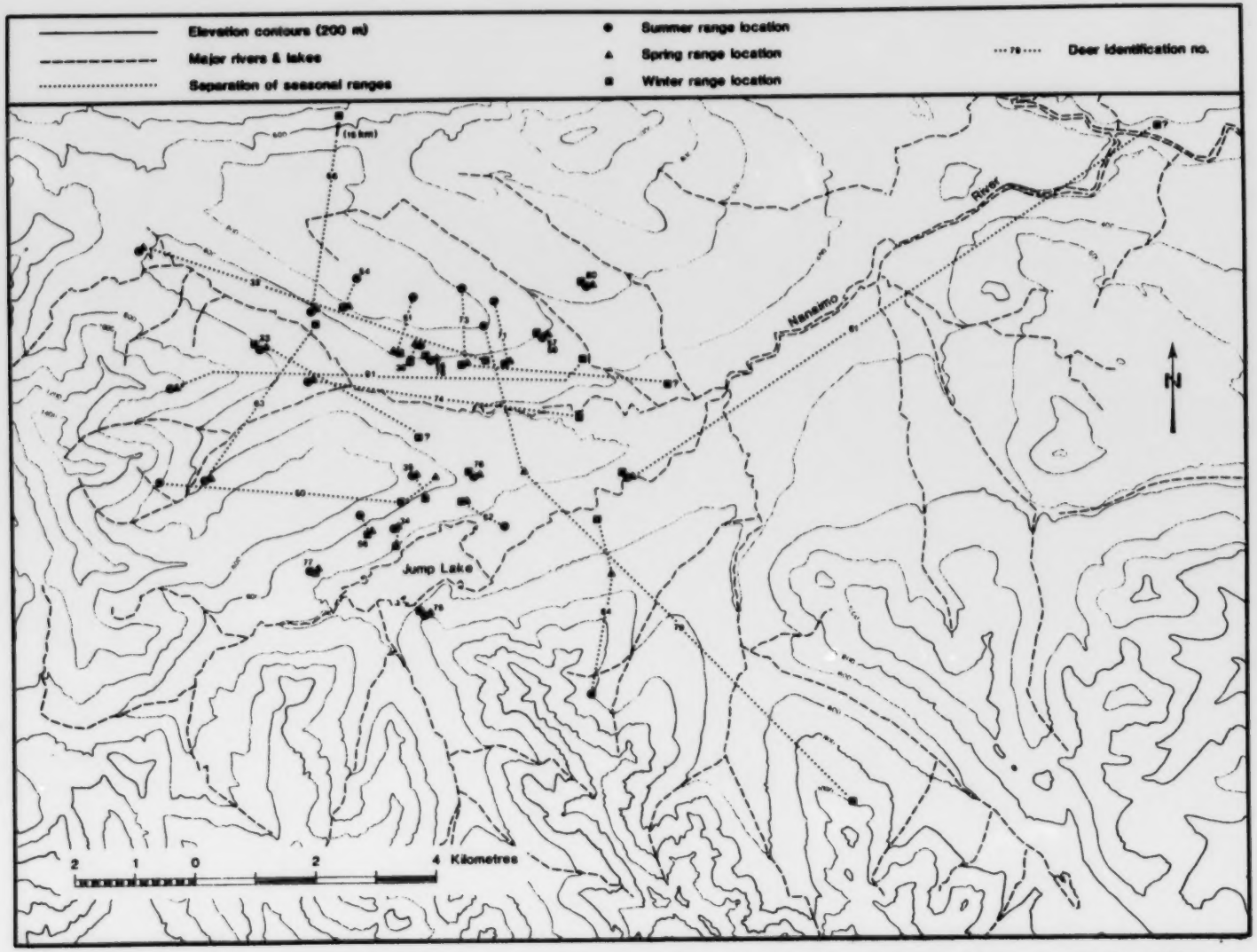


FIGURE 9. Spatial distribution of radio-collared deer and their seasonal home range locations.

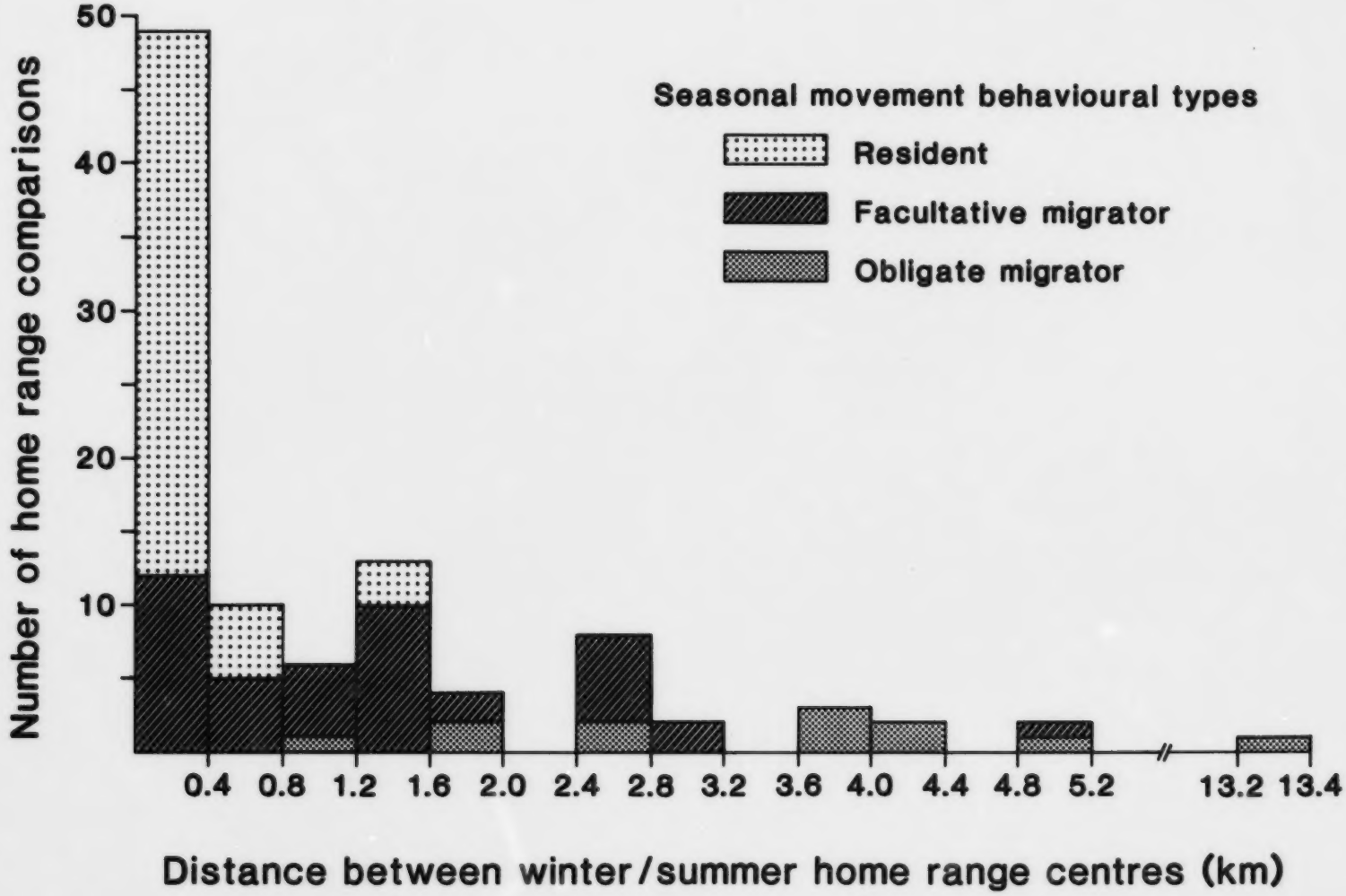


FIGURE 10. Distance between winter and summer home range centres of individual deer.

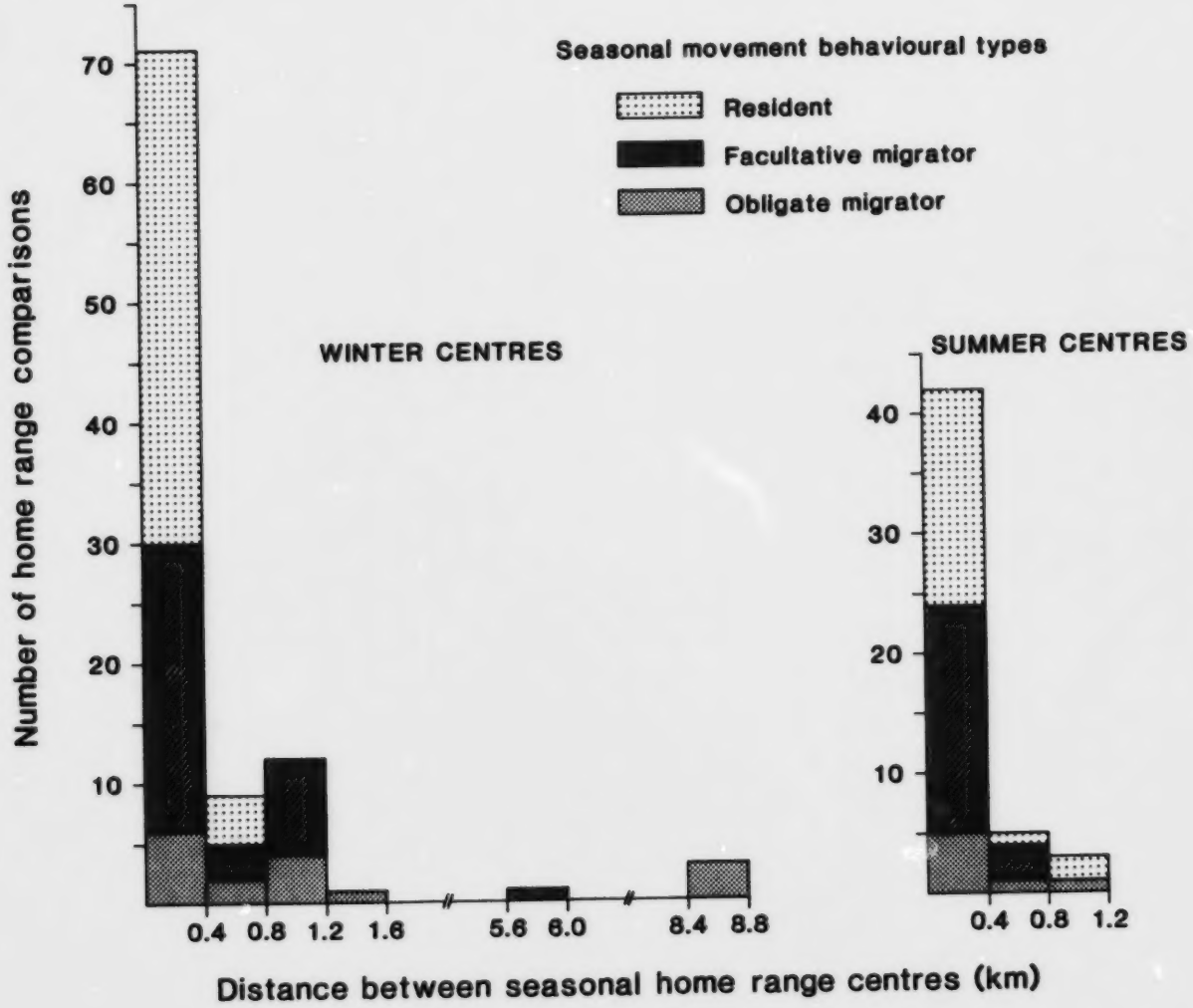


FIGURE 11. Site fidelity to seasonal home ranges.

ranges met the asymptote criterion. At this level the 100 and 90% seasonal home ranges of the obligate and facultative deer were significantly larger than those of the resident deer (Table 2). The 50% home range sizes were not statistically different; most home ranges at this level were less than 20 ha in area (Fig. 12).

2.2.4 Winter habitat use

There was strong individuality in patterns of habitat use, although each deer typically used all successional stages within its winter range. Figure 13 depicts groupings of radio-collared deer based upon their habitat use data. The four habitat use groups are as follows: Group A - deer that used early successional and pole-sapling habitats; Group B - deer that used early successional, pole-sapling, and mixed pole-sapling/old-growth habitats; Group C - deer that used early successional, pole-sapling, and old-growth habitats; and Group D - deer that used all four habitats. Migratory deer tended to locate in areas that had mosaics of habitat types, whereas residents tended to use areas that has fewer habitat types. No residents used all four habitats and no obligate migrators used just early successional and pole-sapling stands (Fig. 13). Deer found in all habitat types (Group D) tended to use their habitats evenly, whereas deer that used pole-sapling and mixed forested habitats (Group B) used the former more than other deer (Fig. 13).

Generally, the radio-collared deer used early successional, old-growth, and subalpine habitats proportionally less expected given their abundance in the map area; mixed pole-sapling/old-growth habitat equal to its map area abundance; and pole-sapling habitat far more than its map area abundance (Fig. 14).

Similar to the seasonal movement patterns that were observed, use of aspect and elevation showed distinct patterns. Resident deer showed little change in use of aspect or elevation from summer to

TABLE 2. Mean seasonal home range sizes and distance between seasonal home range centres

| Seasonal movement behaviour | 100% Home range (ha)±SD | 90% Home range (ha)±SD | 50% Home range (ha)±SD | Sample size (deer seasons) | Distance between seasonal home range centres (km)±SD | n |
|---|---|---|---|---|---|---|
| Obligate migrators | 174.2 (172.4) | 87.7 (95.3) | 13.0 (16.0) | 18 | 4.02 (3.2) | 12 |
| Facultative migrators | 194.8 (319.4) | 99.8 (163.2) | 12.4 (27.2) | 56 | 1.26 (1.9) | 41 |
| Residents | 57.4 (57.1) | 29.7 (25.2) | 5.1 (5.4) | 66 | 0.28 (6.3) | 44 |

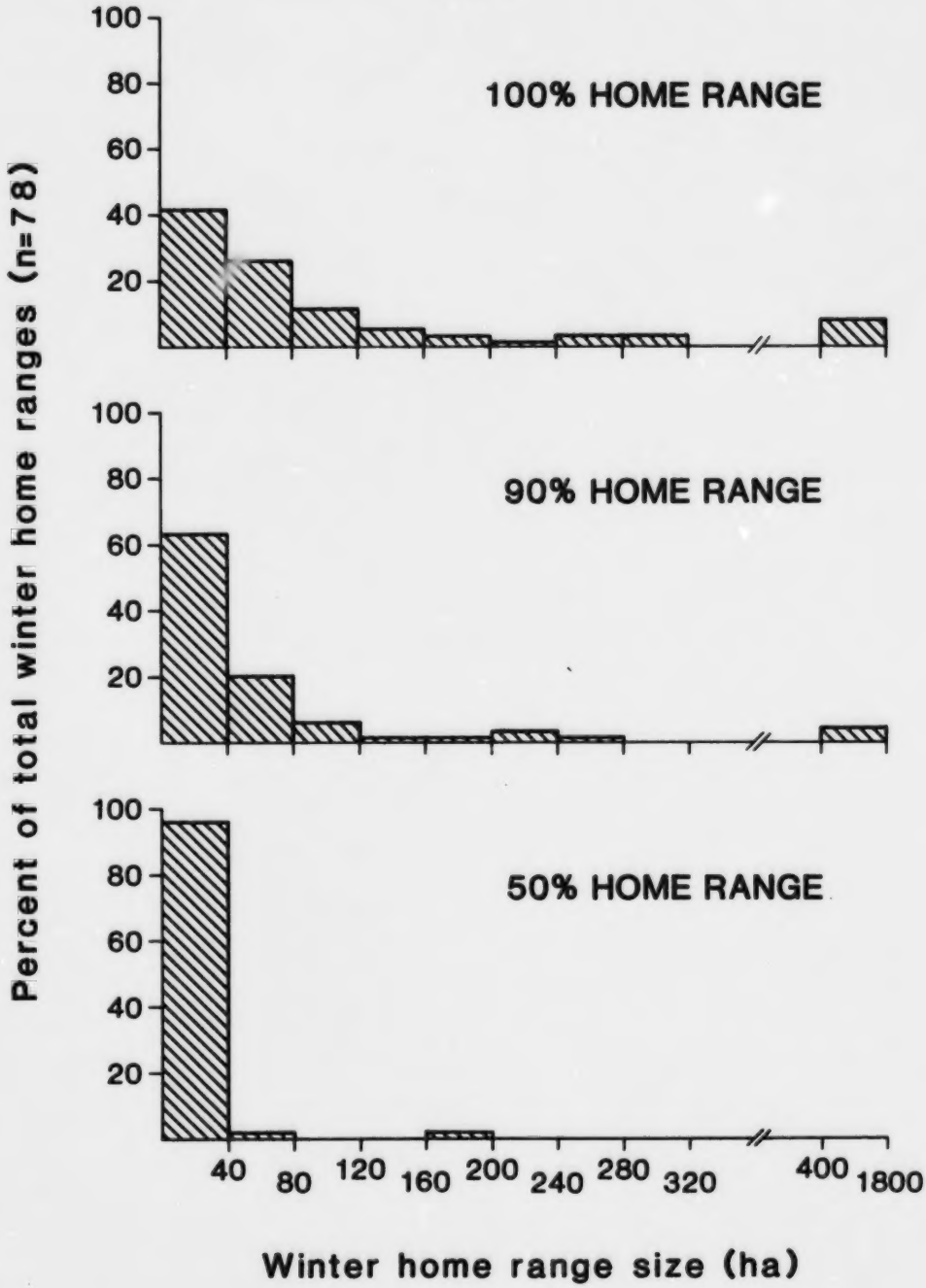


FIGURE 12. The distribution of home range sizes used by radio-collared deer.

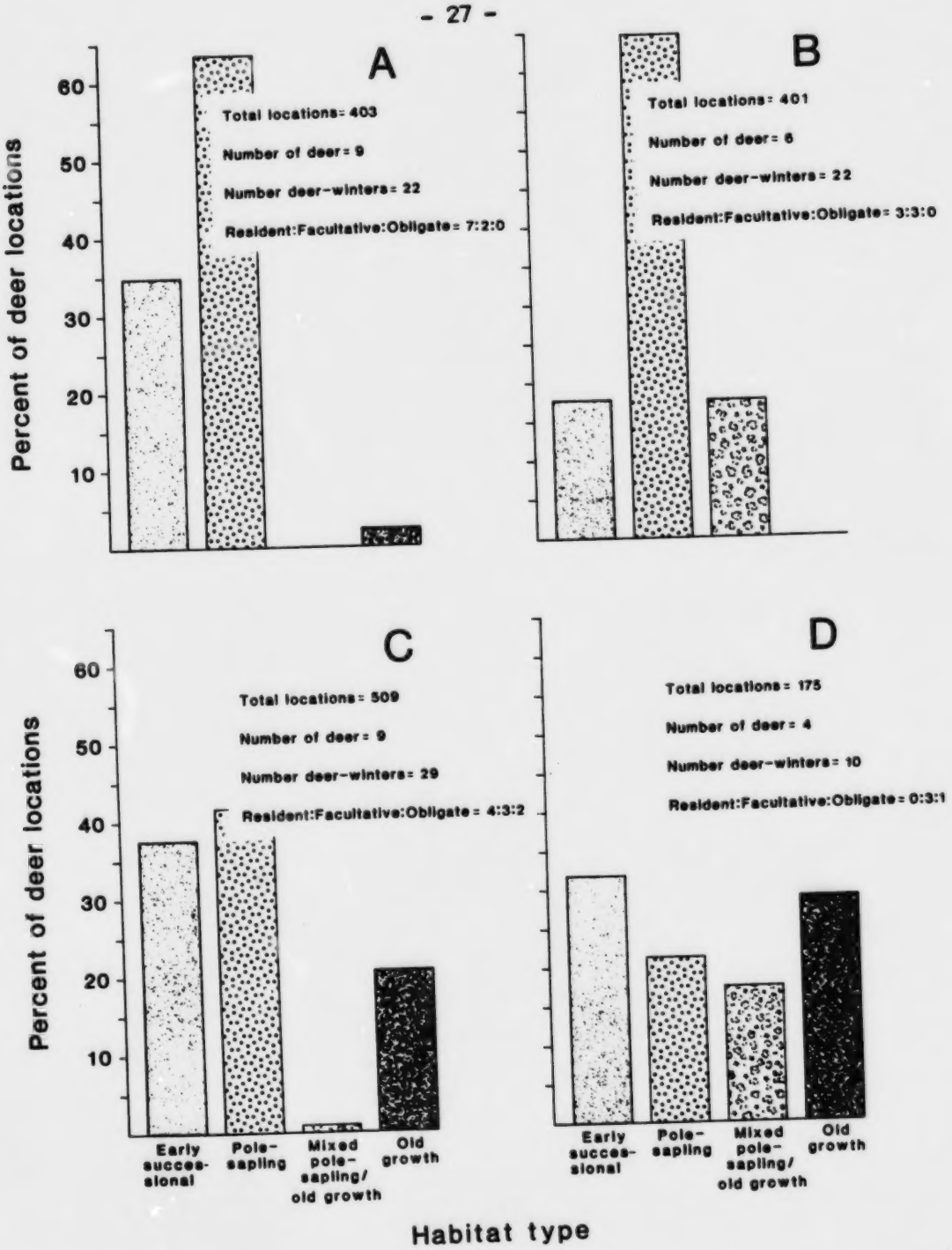


FIGURE 13. Habitat use by radio-collared deer during winter. A, B, C, and D designate groupings of deer by habitat use patterns.

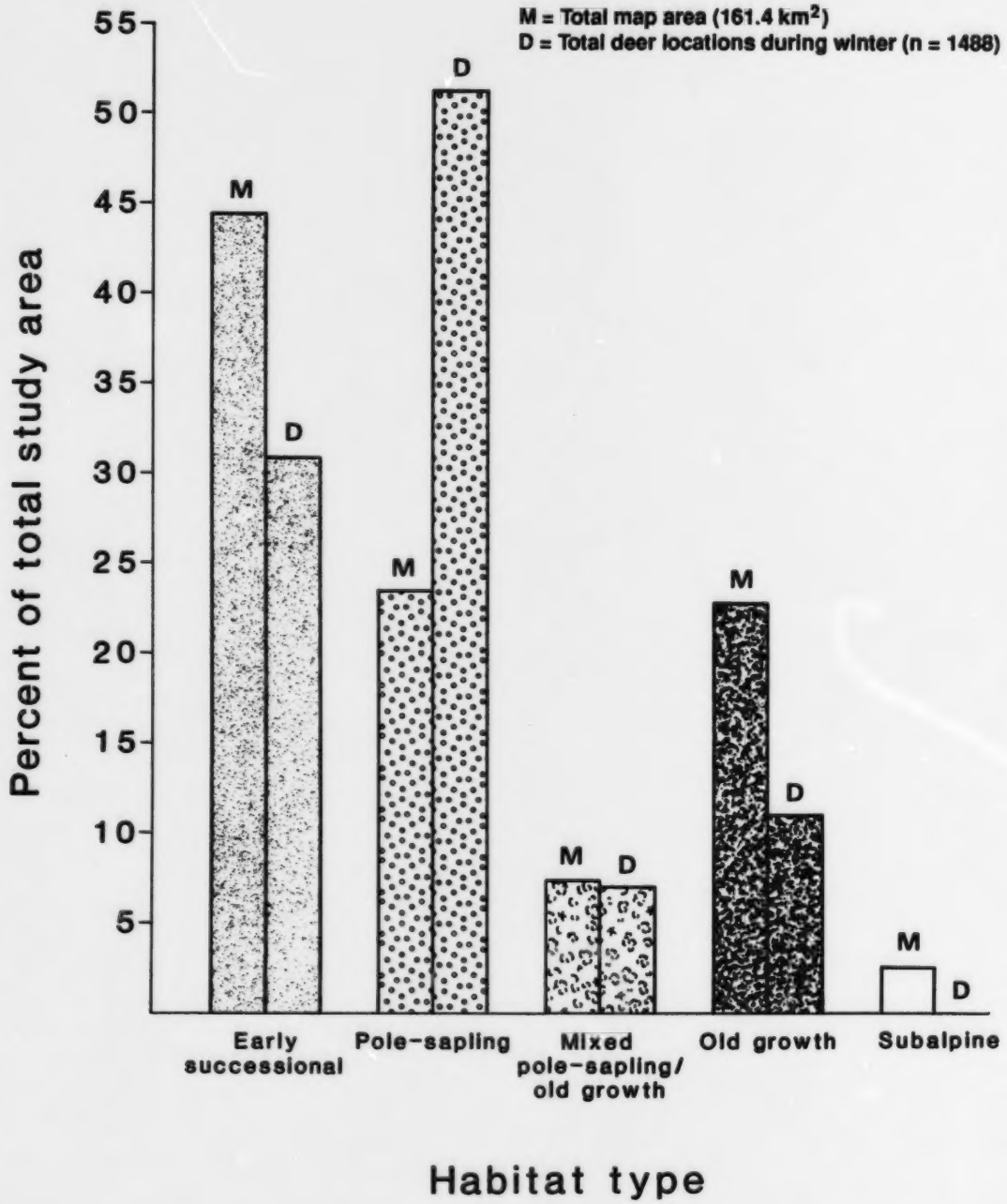


FIGURE 14. Habitat types that compose the study area and that were used by radio-collared deer.

winter (Fig. 15). Facultative migrators shifted to more southerly aspects, while obligates used predominantly south aspects throughout the year. All migratory deer shifted to lower elevations in winter.

## 2.3 Discussion

Migratory and resident behaviour have been well documented in black-tailed deer (Cowan 1945; Harestad 1979; Loft et al. 1984; Schoen and Kirchhoff 1985). Our observation of two types of migratory behaviour (obligate and facultative) may only have been possible because of the mild winter conditions during the study. If snowpack accumulation had been consistent throughout the winter period, facultative behaviour would likely have been masked and all migratory deer would have appeared to be obligate. Schoen and Kirchhoff (1985) in southeast Alaska apparently observed facultative migratory behaviour in deer in response to snow accumulation. Obligate migratory behaviour typifies the movement behaviour studied by McCullough (1964) on black-tailed deer in Oregon. McCullough concluded that the migrations he observed were not a result of habitat changes or drastic changes in winter severity but rather were closely correlated with seasonal changes in relative humidity. Although Harestad (1979) reported obligate migratory behaviour on northern Vancouver Island deer, it was during a study period with more consistent snowpacks.

The proportion of resident deer in our sample (50%) is greater than that reported by Loft et al. (1985) in California (20%), by Schoen and Kirchhoff (1985) in southeast Alaska (25%), and by Harestad (1979) in northern Vancouver Island (30%). Dasmann and Taber (1956) and Brown (1961), on the other hand, found Washington and Oregon deer to be primarily resident. In the case of Brown's data, however, we were unable to evaluate the effect that migration timing would have had on his observations, since relocation of the tagged animals was rare. The extent to which the mild winters had an effect on the frequency of resident behaviour in this study is unclear. The fact that our resident deer did not relocate during periods of deep snow accumulation, as did the facultative deer, supports our supposition that these deer were truly

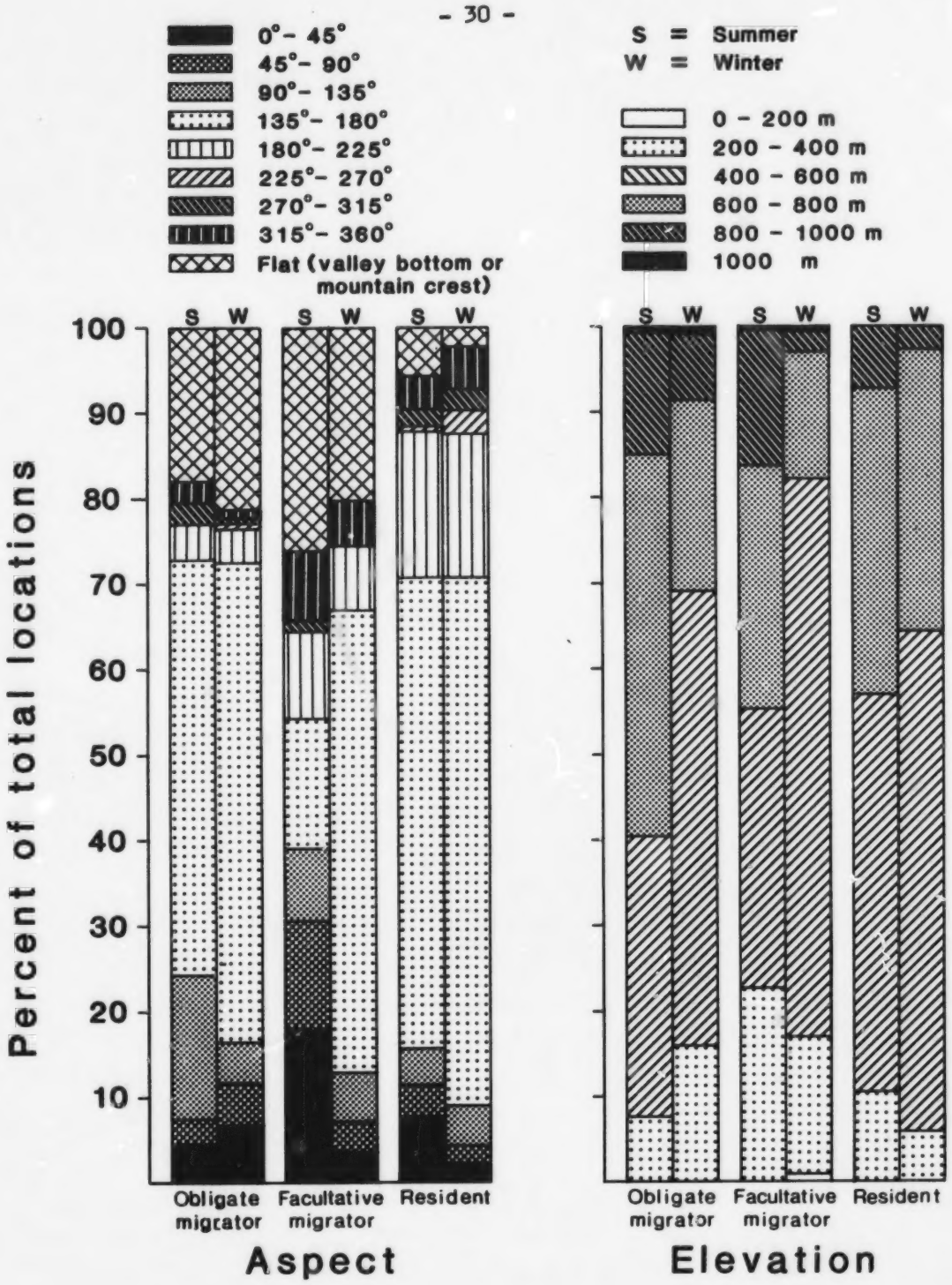


FIGURE 15. Elevation and aspect selection by radio-collared deer.

resident. The availability of high quality summer range at low elevations because of logging may be another factor responsible for the higher proportion of resident deer at low elevations in our study area.

Distances travelled by migratory deer (1-15 km) in this study are typical of those found in the Pacific Northwest (Brown 1961; Harestad 1979; Schoen and Kirchhoff 1985). Unlike those reported in the literature, however, our sample's seasonal movement strategies were apparently not linked to any particular winter habitat location. In Dunsmuir Creek, for example, three deer (see No. 51, No. 78, and No. 55 on Fig. 9) were resident on a south slope. Deer No. 32 migrated 3-4 km to winter in the same location as the resident deer, while deer No. 66 and No. 79 migrated 15 and 8 km, respectively, away from the area to winter elsewhere. Deer No. 73 migrated 1 km to that particular south slope when it snowed; however, if a persistent snowpack accumulated, No. 73 then migrated a further 2-3 km to another winter range, only to return upon snow melt. Thus the same slope is used as a yearly home range, a summer range, a mild winter range, or a severe winter range by different deer. The combination of closed canopied stands (10-40 years old) for thermal and security cover, recent clearcuts for forage production, and the recent series of mild winters probably contributed to the variety of strategies that were observed.

The movement to lower elevations and/or warmer aspects in winter is typical of ungulates in north temperate climates in general (Telfer 1978) and of black-tailed deer specifically (Hines 1975; Harestad 1979; Schoen and Kirchhoff 1985). Changes in elevation were relatively small (200-400 m) as few animals summered above 1000 m. This was because attempts to radio-collar animals was restricted to roaded logging areas, which do not extend to the alpine zones in the study area. A deeper and more persistent snowpack might have produced greater elevational movements.

Although the radio-collared deer exhibited a variety of seasonal use patterns, they showed strong seasonal site fidelity. Most animals returned to the same summer and winter ranges in consecutive years. A few

exceptions did exist in the locations of winter range centres (Fig. 9). The winter range home centre that changed the most from previous years (8 km) was that of deer No. 79. She wintered the first 2 years in a mixed pole-sapling/old-growth stand (both winters were mild), although she made visits to an old-growth stand in November. The last year she remained in the old-growth stand all winter. This actually was only a change in duration of occupation of a seasonal range and not a change in location. The other large shift in winter home range centre (6 km) was that of facultative migrator No. 91. Presumably because of the lack of snow at low elevations in the winter of 1984-85, most radio locations were in the vicinity of No. 91's summer range. Therefore, the CENTRE program selected that area as her winter home range centre for that year. The following winter of 1985-86 had more frequent snowfalls at lower elevations and more locations were in the area of her usual winter range. That type of shift between summer and winter home range during periods of snow accumulation and melt is indicative of facultative migratory behaviour. The same pattern of site fidelity over consecutive years was also found in Sitka black-tailed deer (Odocoileus hemionus sitkensis) in Alaska (Schoen and Kirchhoff 1985).

Unlike Harestad (1979) who found significant differences between seasonal home range sizes in black-tailed deer on northern Vancouver Island, there were no such differences with respect to animals, season, or years in our study area. The low sample sizes within years, and the fact that the majority of seasonal home ranges failed to reach an asymptote, precludes any statistical analysis between years. The larger sample sizes resulting from lumping years makes differences in the 100 and 90% home ranges between migratory and resident deer statistically significant (Table 2). This difference in home range size with respect to behaviour was not found in Sitka black-tailed deer in Alaska (Schoen and Kirchhoff 1985).

Although all deer used early successional (unforested) habitats, twelve of the radio-collared deer made habitat choices whereby only one forested habitat type was used throughout the winter. Nine of these

animals used pole-sapling habitats and three used old-growth habitats. If the radio-collaring of animals was consistent with and representative of habitat selection by the population (i.e., unbiased), then the conclusion would be that pole-sapling habitat is the better of the forested habitat types in winter. Comparing the radio-telemetry data (Fig. 8) with pellet group counts (Appendix 3) and with track counts[5] reveal opposing results, however. Two of the three methods indicate that the sample of radio-collared deer was biased toward deer using pole-sapling habitat. The most successful immobilization technique used was spot lighting in early successional habitats (Appendix 1), which biased our sample of radio-collared deer towards those using early successional habitats that were accessible by road. That bias manifests itself, in part, by weighting the total sample of habitat use locations towards deer using pole-sapling habitats (Fig. 14). The relatively heavy use of the pole-sapling habitats may be further biased upward because deer in these locations were easiest to locate on a regular basis. The conclusion from the observations necessarily reduces to the fact that pole-sapling forests and old-growth forests both can meet the needs of deer during mild winters. Different deer prefer different forested habitat, but no preference for one type was apparent.

Data collection during the summers throughout this study was infrequent and was only used to document seasonal movement behavioural types. The data indicate, however, that a larger number of deer used a single forested habitat (exclusive of other types) during summer than during winter (17 animals versus 12). Sixteen deer used pole-sapling habitat exclusively while only one deer used just old-growth. The observations that deer use old-growth less during summer are supported by data collected elsewhere on Vancouver Island (Harestad 1979) and Oregon (McCullough 1964). The conclusion is that pole-sapling habitats were the

---

[5] Nyberg, J.B., L. Peterson, L.A. Stordeur, and R.S. McNay. [1987]. Deer use of old-growth and immature forests following snowfalls on southern Vancouver Island. B.C. Min. For. Lands, Res. Branch, Victoria, B.C. In preparation.

forested habitat type used most heavily year-round during a period of relatively mild winters.

During winter, 4 of 14 migrators (and no obligate migrators) chose just one forested habitat exclusively while 8 of 14 resident animals chose one forested habitat exclusive of others. During summer 8 of 14 migrators (all obligate migrators) chose a single forested habitat, as did 9 of 14 resident animals. Migratory deer, especially obligate migrators, tended to locate in areas with habitat mosaics during winter and tended to choose pole-sapling habitat exclusively during summer. All but one resident animal had access to pole-sapling and half the residents chose pole-sapling exclusively.

Regardless of whether or not the radio-collared animals reflect the proportional occurrance of behaviours in the population, the seasonal shifts in habitat use indicate a preference for pole-sapling as the forested part of the summer habitat complex. Migrators showed more selection for a single forested habitat during summer than during winter. The strategy in the winter seems to be to select for habitat mosaics that afford at least some access to old-growth (only 2 of 14 migrators did not have access to old-growth).

Studies from locations with less manipulated habitats and/or more consistent and severe winters show high proportions of migratory deer relative to resident deer (Harestad 1979; McCullough 1964; Schoen and Kirchhoff 1985). The abundance of resident deer in this population is postulated to be in response to an abundance of available, low elevation summer habitat (brought about by logging) that can double as winter habitat during mild winters. The population as a whole appears to have sufficient flexibility to adapt to habitat manipulation, particularly during mild winters.

Such a shift in population characteristics raises the question and concern about the ability of the population to withstand or recover from (i.e., resiliancy) a catastrophic occurence such as a severe winter. Hard winters could be more detrimental to current populations than was experienced previously on Vancouver Island (Smith 1969; Jones and

Mason 1983); migrators indicate that old-growth habitat is the best severe winter range but the population is becoming increasingly resident as old growth decreases. Resident deer chose primarily pole-sapling habitats during winter for reasons that do not necessarily relate to the adaptive qualities of that habitat as severe winter range. Thus they represent a segment of the population that is potentially vulnerable to excessive mortalitiy during severe winters.

## 3 HABITAT PREFERENCE BY BLACK-TAILED DEER DURING SPECIFIC WINTER WEATHER EVENTS

Generally, the purpose of habitat selection studies is to identify which habitat types are used by animals on a seasonal basis. That information by itself is usually not interesting to either the wildlife manager, the habitat manager, or the forester unless the animal is rare or little known. In combination with a known quantity of available habitat the data can imply preference, especially if sample sizes are high and one or more habitats is used more than would be expected based on simple probability. Preferred habitats are assumed to provide resources that satisfy a large part, if not all, of the factors that an animal needs to survive; this does not imply the animal requires that habitat to survive, since it is unknown if all of the needs could be obtained from other less preferred habitat types. Required habitats are rarely identified by wildlife studies except in extreme situations because several instances of complete elimination of the required habitat are needed for proof. The more traditional approach in wildlife studies is to document preference and add retroductive hypotheses concerning why certain habitat may be required (Romesburg 1981).

Although documenting preference is likely the most practical method of approaching wildlife habitat problems, it has historically had only limited success. The primary reasons for the lack of effectiveness lie in two common technical assumptions: 1) that preference implies requirement; and 2) that actual habitat availability resembles habitat availability as perceived by the investigator.

The statistical definition of preference relies on the investigator's perception of availability (Johnson 1980). The usual result is a difference in quantification of preference depending upon the statistical techniques used (Krueger 1972). Alldredge and Ratti (1986) found that factors such as the number of animals used, the number of locations per animal, and the magnitude of preference difference to be detected all significantly affect the occurence of type II errors for the overall hypothesis (i.e., concluding that all habitats were preferred equally when in fact they were not).

Our objectives were to evaluate habitat preference by black-tailed deer during specific winter weather events, with techniques that did not depend on the measure of habitat abundance, but on multiple comparisons of specific habitat use distributions (i.e., use/use comparisons rather than traditional use availability comparisons). By identifying the habitats favoured by deer during specific types of weather, we hoped to determine the habitat conditions they preferred, and to identify those features that should be enhanced by stand management.

## 3.1 Methods

Twenty-six deer that were fitted with radio collars for a related study (Section 2) were used to determine habitat selection patterns during specific winter weather events. Details on equipment and procedures used for collaring the animals are presented in Section 2 and Appendix 1. Animal locations were determined once every 2 hours by remote telemetry using a minimum of three bearings taken from known locations in the field. In light of previous experience with intensive telemetry and especially with the concern regarding observer effects during intensive telemetry schedules (Swihart and Slade 1985), we abandoned initial attempts to monitor deer every 15 minutes. The 2-hourly samples were continued for the full 24 hours of each day throughout the intensive-monitoring sessions. All telemetry stations were located on a 1:20 000 planimetric map and their Universal Transverse Mercator (UTM) grid co-ordinates were recorded and filed for use with "POLYGON" a computer assisted method of calculating animal locations. The number of

polygon sides, the size of the polygon, and distance to the animal's location were criteria used to determine the relative usefulness of the radio telemetry data (Page 1982). Error polygons in excess of 4 ha were usually considered unreliable and excluded from further analysis. Thirty-three samples with error polygons greater than 4 ha (1.4% of the total sample) were retained because site-specific knowledge enabled reasonable confidence in the actual location of the animal.

Snow depth was monitored each day of intensive telemetry. Maximum and minimum temperatures and wind speeds were recorded every 3 hours with the use of a battery operated CR-21 weather data logger (Campbell Scientific Canada Inc., Edmonton, Alta.).

Weather patterns and periods under which to monitor habitat use were selected prior to field work (Nyberg et al. 1985). A set of hypotheses were developed about the factors that attract deer to various types of habitats during particular weather. These included information on available forage, snowpack conditions, and a combination of the two. Based on those factors, habitat selection by deer was intensively monitored during the following conditions:

1. snowfalls of more than 7.5 cm in a 24-hour period;
2. windy conditions that generate large amounts of conifer and lichen litterfall in old growth;
3. the formation of strong crusts in the snowpack;
4. melt of more than 10 cm of snow as measured at roadside snow stations in a 48-hour period, particularly when this changes forage availability dramatically in some habitats; and
5. the first appearance of the ground surface in clearcuts after 14 days or more of continuous snow cover.

Home range size and activity centres were defined and analyzed using the same techniques described in Section 2. Habitat use groups were defined using data from Section 2 where classifications of deer were as follows: Group A - deer that used early successional and pole-sapling

habitats; Group B - deer that used early successional, pole-sapling, and mixed pole-sapling/old-growth habitats; Group C - deer that used early successional, pole-sapling, and old-growth habitats; and Group D - deer that used all four habitats. Seasonal movement behavioural types (obligate migrators, facultative migrators, and resident) were also defined as in Section 2.

Frequency distributions of habitat use were compared among individual deer, habitat use groups, and seasonal movement behavioural types using chi-square tests (SAS Institute Inc. 1985). Differences between night-time (18:00 hr - 8:00 hr) and day-time (8:00 hr - 18:00 hr) use of habitats were also investigated by chi-square analysis. The predictability of habitat use was investigated using categorical data modelling techniques (SAS Institute Inc. 1985). The observed responses of the deer (habitat use) were expressed as a function of weather categories (Fig. 17), seasonal movement behavioural types, and habitat selection groups. Maximum- likelihood estimation was used to test the significance of the model.

The terms "use", "selection", and "preference" are often used indiscriminately in the literature. In this study we adopted similar definitions to those provided by Gillingham (1985). Habitat availability implies that habitats are accessible to the animal. A habitat polygon was considered available if $np$ and $n(1-p) \geq 5$, where $n$ is the total number of times the animal was relocated and $p$ is the probability of being found in that particular polygon (Hayes and Winkler 1970, cited by Neu et al. 1974). We assumed that because such a polygon was used, then the animal had knowledge of it and it was available for further use. Use was considered synonymous with selection because an animal must select a habitat if it is to use it (i.e., habitats were not used randomly). Preference was assumed to mean that, given equal chance or probability of using a mosaic of habitats, one or more habitats was chosen more frequently than would be predicted.

Straight line distances between consecutive 2-hour locations were calculated and Duncan's multiple range tests (SAS Institute Inc. 1985)

were employed to determine differences in average mobility of deer during different weather conditions.

## 3.2 Results

### 3.2.1 Sample conditions

Eight separate sessions of intensive monitoring were conducted over 4 years to identify habitat selection by deer during specific winter weather events. Three of the monitoring periods occurred during relatively mild winter weather (calm winds and temperatures $> 0°C$), one during mild, windy conditions, one during cold temperatures, two during periods of snow accumulation, and one following a period of rapid snow ablation. Altogether, the samples totalled 2417 animal locations and 76 animal-sessions (Fig. 16 and Appendix 2).

Three-hourly temperature (maximum and minimum) and windspeed traces for each of the eight monitoring periods are provided in Figure 17. Periods one, two, four, and five were similar in that the weather conditions were mild; however, period one had higher than normal winds. Period seven was also fairly mild, being at the end of a strong snow ablation trend, and period three was characterised by cold temperatures. Periods six and eight were sampled because of the significant snow accumulations at those times (Section 2; Fig. 6).

### 3.2.2 Centres of activity

We compared the centre of activity measured during a particular intensive-monitoring period to the centre of activity that was measured from weekly telemetry for the entire winter of the same year (Section 2). Shifts in the centre of activity during particular weather events were, for the most part, insignificant ($P > .10$) and short. Typically, activity centres were $< 50$ m apart (Table 3) except during cold, windy, or snowy periods when deer tended to make subtle shifts towards the closest forested habitat (Fig. 18). The only exceptions were five shifts (100-630 m) that were made by

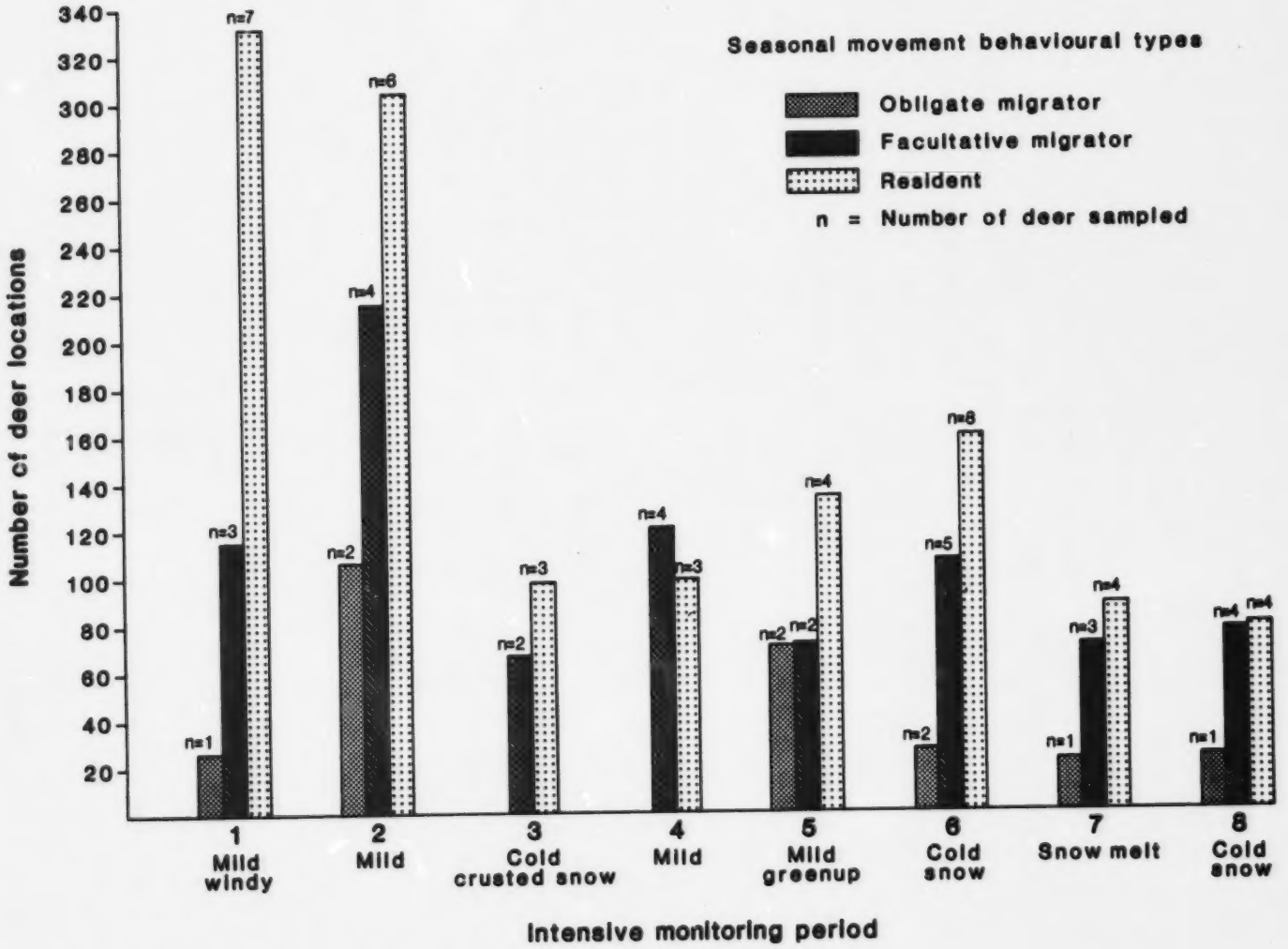


FIGURE 16. Data summary for deer locations (intensive monitoring).

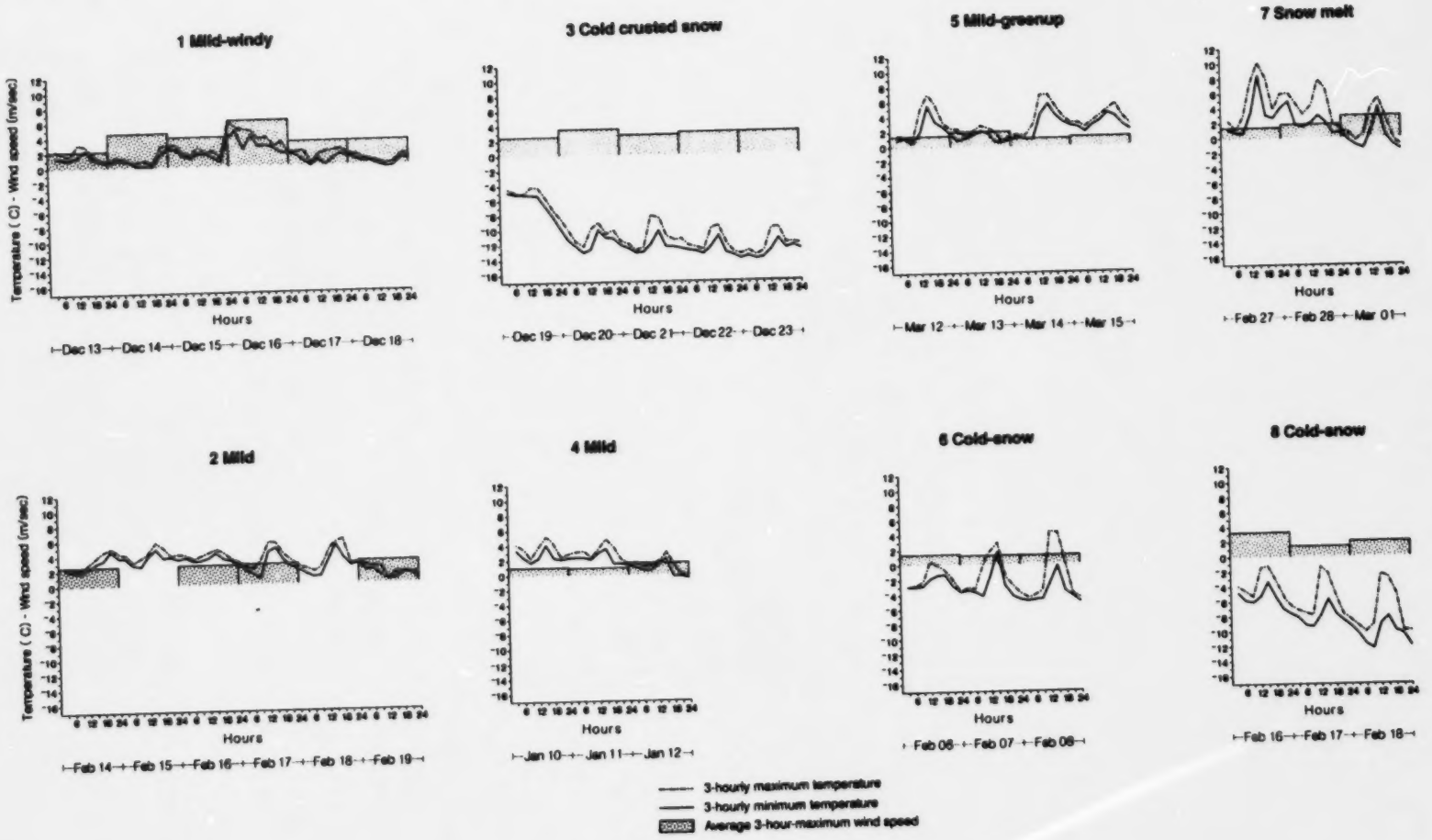
1 Mild-windy
Temperature ( C) - Wind speed (m/sec)
Hours
Dec 13 Dec 14 Dec 15 Dec 16 Dec 17 Dec 18
3 Cold crusted snow
Hours
Dec 19 Dec 20 Dec 21 Dec 22 Dec 23
5 Mild-greenup
Hours
Mar 12 Mar 13 Mar 14 Mar 15
7 Snow melt
Hours
Feb 27 Feb 28 Mar 01
2 Mild
Temperature ( C) - Wind speed (m/sec)
Hours
Feb 14 Feb 15 Feb 16 Feb 17 Feb 18 Feb 19
4 Mild
Hours
Jan 10 Jan 11 Jan 12
6 Cold-snow
Hours
Feb 06 Feb 07 Feb 08
8 Cold-snow
Hours
Feb 16 Feb 17 Feb 18
3-hourly maximum temperature
3-hourly minimum temperature
Average 3-hour-maximum wind speed

FIGURE 17. Three-hourly maximum and minimum temperatures and daily average windspeed traces for each of the eight intensive monitoring periods.

facultative migrators enroute to forested habitat during periods of snow accumulation.

### 3.2.3 Home range sizes

Weather (categories defined from intensive monitoring periods; Fig. 17) accounted for 52% of the variation in the 100% home range sizes ($P < .01$), 49% of the 90%-home range sizes, and 60% of the 50% home range sizes. The most obvious shifts in home range size came with cold and/or snowy conditions when deer, regardless of residency behaviour, cut their home area in half (Table 3). Within particular monitoring periods, too few deer could be followed to allow identification of behaviour-related influences on home range size.

The pooled intensive-monitoring data were not statistically different from the regular-monitoring data for any level of home range size determination. Unlike the data collected from regular monitoring (Section 2), residency was only a weak factor contributing to home range sizes.

### 3.2.4 Habitat use

Habitat use was slightly but significantly ($P < .05$) different than the patterns measured during the regular-monitoring schedule (compare Fig. 13 in Section 2 with Fig. 19). Deer that traditionally used all habitat types (Group D) tended to use pole-sapling stands 35% more in the pooled intensive-monitoring data while reducing the use of old-growth and early successional stages. Deer that only used pole-sapling and early successional sites (Group A) reduced the use of early successional sites by 9% and deer that used pole-sapling, mixed pole-sapling/old-growth, and early successional habitats (Group B) reduced their use of early successional sites by 7%. There was no significant difference between the regular and intensive data sets in comparisons of deer that traditionally used pole-sapling, old-growth, and early successional sites (Group C, Fig. 19). When use of forested and early successional habitats was compared, there

TABLE 3. Mean home range sizes (standard deviation) and distances[a] between activity centres (intensive monitoring)

| Period | | 100% Home range (ha) | 90% Home range (ha) | 50% Home range (ha) | Distance between activity centres (m) | Sample size |
|---|---|---|---|---|---|---|
| 1 | Mild-windy | 55.9 (27.9) | 21.0 (12.7) | 3.4 (2.9) | 3.0 (10.9) | 11 |
| 2 | Mild - crusted snow | 53.9 (37.9) | 26.4 (17.7) | 4.7 (4.6) | 32.7 (30.6) | 12 |
| 3 | Cold | 42.9 (40.6) | 15.3 (11.6) | 0.9 (0.5) | 124.0 (234.8) | 5 |
| 4 | Mild | 35.4 (18.3) | 23.1 (14.8) | 3.6 (2.2) | 33.8 (23.4) | 7 |
| 5 | Mild - greenup | 26.9 (22.9) | 12.7 (6.4) | 1.9 (1.1) | 42.1 (28.7) | 8 |
| 6 | Cold - snow | 10.0 (10.4) | 5.8 (4.3) | 0.9 (0.8) | 42.5 (80.8) | 15 |
| 7 | Snow melt | 21.0 (9.6) | 13.9 (7.0) | 1.9 (1.5) | 54.4 (73.0) | 8 |
| 8 | Cold - snow | 14.2 (8.5) | 10.7 (7.3) | 2.0 (1.3) | 117.0 (205.2) | 9 |
| | All mild periods | 45.4 (30.7) | 21.4 (14.3) | 3.5 (3.2) | - | 38 |
| | All cold-snowy periods | 17.8 (19.4) | 10.0 (7.6) | 1.4 (1.1) | - | 37 |
| Total intensive monitoring | | 101.9 (109.8) | 50.1 (53.9) | 7.8 (7.0) | - | 75 |
| Regular monitoring[b] | | 159.6 (252.1) | 80.6 (115.6) | 9.7 (17.2) | - | 25 |

[a] Distances calculated are between centres of activity for the period and the regular monitoring schedules for the particular winter during which the intensive monitoring occurred.
[b] Calculations were for only those animals that were sampled during intensive monitoring schedules.

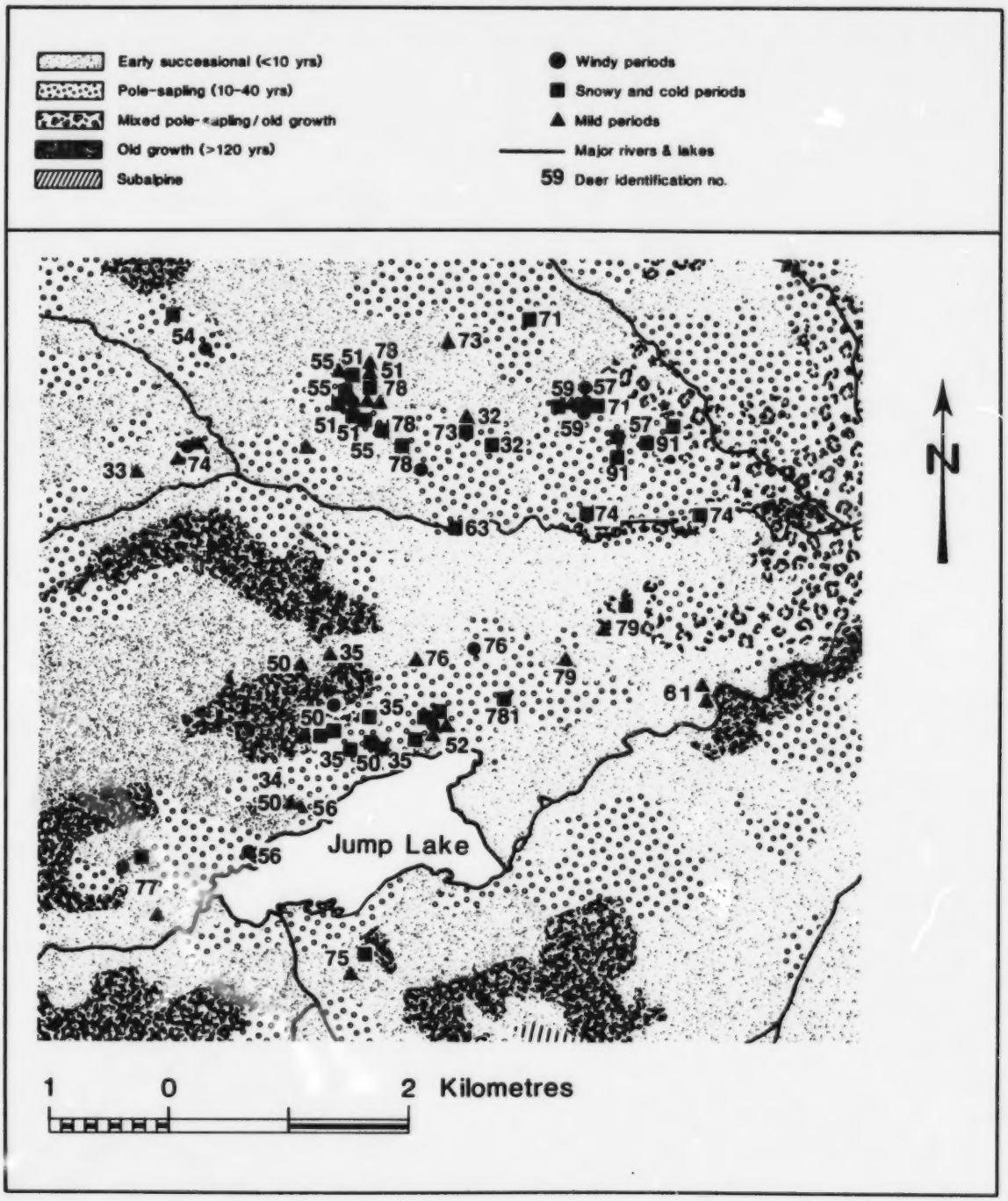


FIGURE 18. Activity centres for radio-collared deer during warm, cold-snowy, or windy weather.

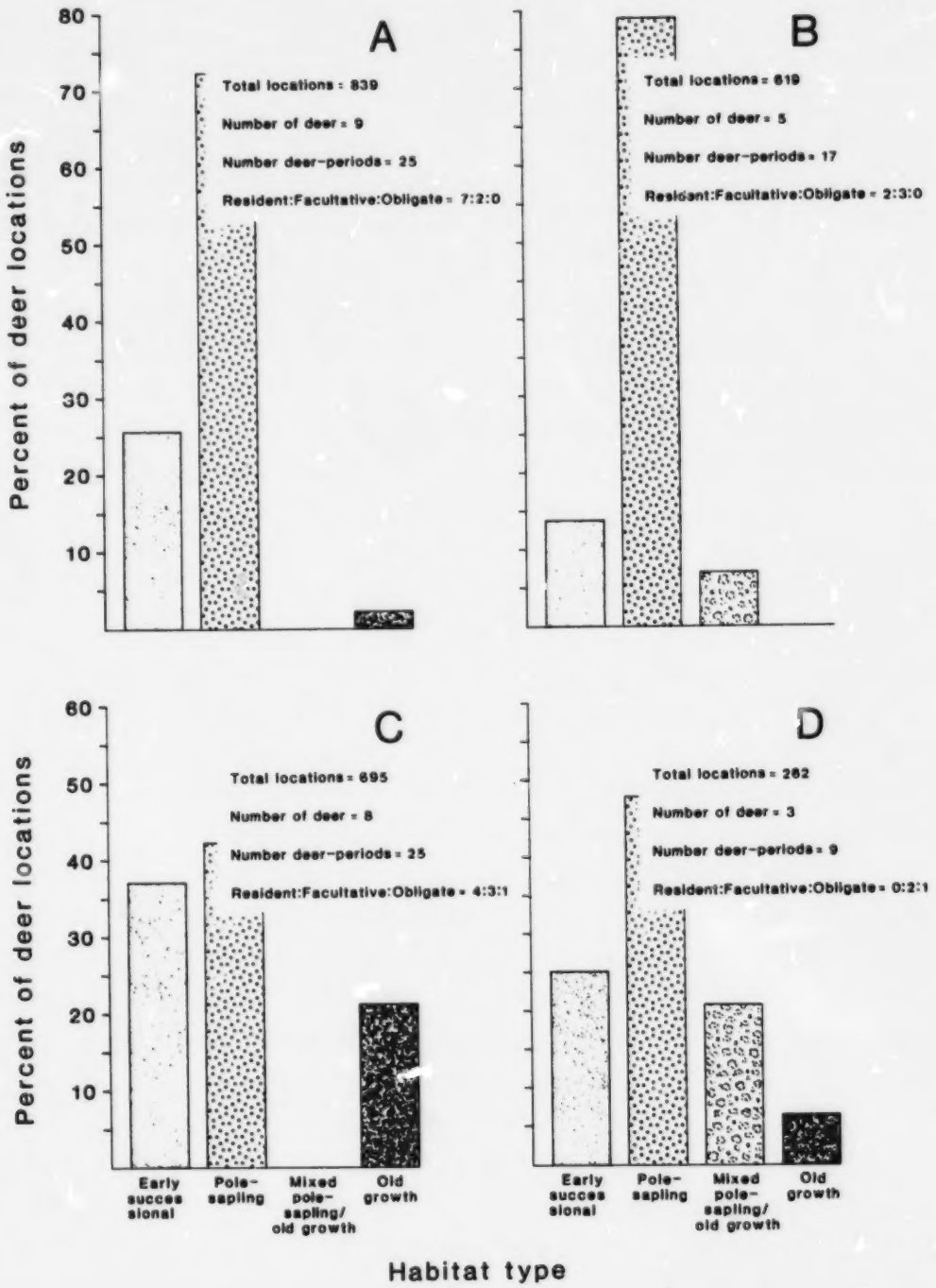


FIGURE 19. Habitat use by radio-collared deer (intensive monitoring).

was no statistical difference between data sets for the deer in Group D nor for those deer in Group C.

Use of habitats was significantly different between night and day. The pooled-intensive data set showed a 3% use of mixed pole-sapling/old-growth habitat and a 7-8% use of old-growth forest, neither of which changed from night to day. The use of early successional sites, however, changed from 19% daytime use to 31% night-time use. Use of pole-sapling stands changed from 70% daytime use to 58% night-time use. Deer that used early successional, pole-sapling, and either old-growth or mixed pole-sapling/old-growth habitats (Group B and Group C) changed least in their use of early successional habitats with an increase in night-time use of 7 percentage points; deer that used all habitats (Group D) changed most with an increase of 25 percentage points.

Periods with mild weather were more closely related to each other than to the pooled data set. Similar results were observed for the cold, snowy, and windy periods (Fig. 20), during which the use of early successional habitat types decreased. Deer showed more variation in their habitat use during mild conditions than during cold, snowy, or windy periods.

Categorical modelling techniques failed to reveal a significant model for the prediction of habitat use patterns as a function of seasonal movement behavioural types, habitat selection groups, and weather conditions. All factors were significant ($P < .05$) with the saturated model, but those results were suspect because residual variation was highly significant in reduced models.

### 3.2.5 Mobility

The straight-line distance between successive 2-hourly locations was used as an index of mobility during the monitoring periods. Distances calculated from locations more than 6 hours apart (241 cases) and those resulting from facultative migrations (18 cases)

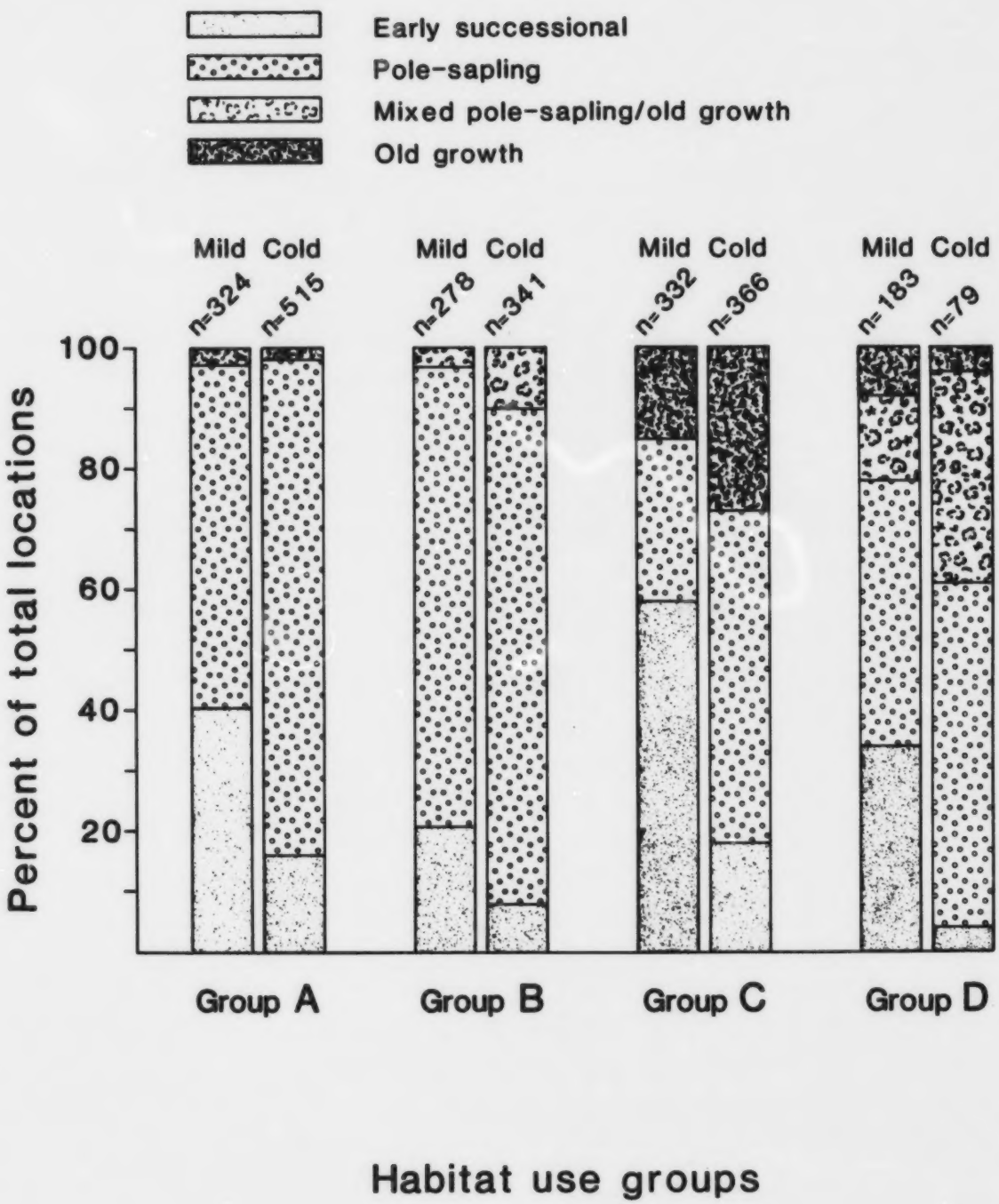


FIGURE 20. Proportional use of habitats during mild and cold-snowy weather conditions.

were removed from the data set. The correlation of elapsed times of 1-6 hours with distance travelled was extremely weak ($r^2$=.001); these data were therefore analyzed further (n=2130).

With the exception of one mild period during spring green-up (monitoring period number 5), the mean distance travelled between locations during mild weather were not different. Mean distances moved during cold and/or snowy weather (periods 3, 6, and 8) were also not significantly different. Deer moved 22% longer distances between successive locations during the mild weather monitoring periods than during the cold-snowy weather monitoring periods (Table 4). There was no difference between seasonal movement behavioural types during cold-snowy weather, but obligate migrators moved 33 and 43% longer distances than resident or facultative migrators, respectively, during mild weather. Deer that used open, old-growth, and pole-sapling habitats (Group C) moved 45% greater distances than deer that used just open and pole-sapling habitats (Group A) during mild weather; but both groups moved similar distances during cold weather (Table 4). During cold-snowy weather, habitat selection Group D moved 63% more than Group B and 23% more than both Group A and Group C.

## 3.3 Discussion

The seasonal movement behavioural types and habitat selection groups of deer, as they were defined in Section 2, prevailed for all intensive monitoring periods. Behavioural types influenced most habitat type selection patterns as well as the methods of habitat use (Fig. 19 and Table 4). It was clear that once residents and obligate migrators had established a winter home range they would continue to use that area as best they could throughout any kind of weather, similar to deer studied by Dasmann and Taber (1956) and Schoen and Kirchhoff (1985). As a result, home range centres measured during intensive monitoring sessions were not different from those recorded during the rest of the winter. Facultative

TABLE 4. Deer mobility index during mild and cold-snowy weather

| Deer groups | Weather condition | Average distance moved (m) | Standard error (m) | Sample size (n) | Multiple-comparison test[b] |
|---|---|---|---|---|---|
| Seasonal movement behavioural types | | | | | |
| Resident | mild | 178 | 7 | 722 | A1 |
| | cold-snowy | 142 | 7 | 429 | B1 |
| Facultative migrator | mild | 166 | 8 | 466 | A1 |
| | cold-snowy | 146 | 11 | 265 | B1 |
| Obligate migrator | mild | 238 | 20 | 132 | A2 |
| | cold-snowy | 169 | 14 | 116 | B1 |
| Habitat selection groups[a] | | | | | |
| A | mild | 172 | 8 | 510 | C1 |
| | cold-snowy | 150 | 10 | 243 | D1 |
| B | mild | 172 | 9 | 423 | C1 |
| | cold-snowy | 113 | 9 | 150 | D2 |
| C | mild | 250 | 14 | 251 | C2 |
| | cold-snowy | 149 | 8 | 320 | D1 |
| D | mild | 106 | 10 | 136 | C3 |
| | cold-snowy | 185 | 19 | 97 | D3 |
| Pooled groups | mild | 180 | 5 | 1320 | E1 |
| | cold-snowy | 147 | 5 | 810 | E2 |

[a] Where A = deer using open and pole-sapling habitats.
B = deer using open, pole-sapling and mixed pole-sapling/old-growth.
C = deer using open, pole-sapling and old-growth.
D = deer using all habitat types.

[b] Means with the same letter codes are not signficiantly different ($P < .05$).

migrators, on the other hand, usually moved at the onset of inclement weather, apparently in search of better habitat conditions.

Forested habitats were consistently preferred over early successional stages during inclement weather (Figs. 18 and 20). This preference for forested types was interpreted as a preference for overstory cover from wind and snow, a greater abundance of available forage, and a warmer thermal environment than could be provided in early successional stages. This retroductive speculation could be tested using a design similar to that of Leckenby and Adams (1986). With data from Parker,[6] hypotheses could be made regarding thermal stresses on deer during winter; and the "TEMP" and "WIND" indices used by Leckenby and Adams could be adjusted to suit black-tailed deer (their model was for mule deer [Odocoileus hemionus hemionus]).

Resident deer of pole-sapling habitats had only two habitat choices available to them (availability being based on the data from regular locations; Section 2). During snowy weather, their early successional habitats accumulated snow deep enough to cause a barrier to locomotion and to bury most food.[7,8] As a result, those deer restricted their habitat use to pole-sapling habitats only. Sampling of snow and forage in the forested habitats failed to reveal any clear benefit that could have been provided by moving into old growth or mixed pole-sapling/old growth.[9,10] Old growth consistently received more deer use according to the track frequency index adopted during that related study. Old growth usually had the least snow as well. More food was available in pole-sapling habitats, however, with the one exception of lichens. It is important to note that 8 of 10 facultative migrators and all obligate migrators followed during intensive telemetry chose at least one other

---

6 Parker, K.L. 1986. Interim report: Te for black-tailed deer (Odocoileus hemionus columbianus). B.C. Min. Environ. Parks and Min. For. Lands, Victoria, B.C. 25 p. Unpubl. report.
7 Page and McNay. [1987]. In preparation.
8 Nyberg et al. [1987]. In preparation.
9 Page and McNay. [1987]. In preparation.
10 Nyberg et al. [1987]. In preparation.

forested habitat besides pole-sapling stands (Fig. 19). Migrators appear to alter their habitat choices conditionally (in the case of facultative migrators) or position themselves where they have maximum choices of habitat (in the case of obligate migrators), while residents use only those habitats within a certain proximity (i.e., for our resident sample, mainly pole-sapling and early successional habitats).

To the best of our knowledge each of these strategies was successful during the mild winters experienced in this study. (Although only three deer died of malnutrition [see Appendix 2], the fact that collar life on these animals was less than a full year precluded any assessment of the influence of behaviour type.) Because all strategies were apparently successful we were unable to identify specific forest characteristics commonly preferred by deer during inclement winter weather. Instead of a population-wide strategy, different groups of deer preferred different forest characteristics.

The reduction in flexibility of habitat use during cold-snowy weather, coupled with decreased home range size and reduced mobility (Section 2), and activity (Appendix 6), all indicate the considerable effect of weather on life maintenance strategies of deer. Nudds (1980) argued that because of the small body size of deer, relative to other ungulates, deer can be nutrient-optimizers (diet specialists) when resources are abundant but should shift to energy-maximizers (diet generalists) when resources become limited. Data from a study of the foraging behaviour of penned black-tailed deer (Gillingham 1985) support that hypothesis. Intake rates of non-preferred foods increased with declining abundance of preferred foods. That response, however, was more functionally related to encounter rate than to overall abundance.

If Nudds' hypothesis holds for deer in our study, it would explain the relatively high preference for lichen shown by deer that used old-growth forests during winter (Appendix 4), and would perhaps help to explain the apparent willingness of deer (particularly habitat selection Group A) to use whatever habitats were within their home range. Deer

probably attempted to minimize energy expenditure by selecting forested habitats, which have less snow than early successional habitats.[11] That particular response to cold winters and deep snow is commonly cited, and is most obvious for deer that yard in the winter (Ozoga and Gysel 1972). Assuming that deer shift from being diet specialists to being diet generalists at the same time they shift habitat use, the prime requisite becomes not what nutritious food is available, but how much highly digestible food is available. Forage sampling (excluding lichens) in the study area during snow accumulations (15-30 cm) revealed that more food was available in pole-sapling stands than old-growth stands.[12] Weighting the observations by digestibility values from Table A4.4 does not alter that conclusion. However, if lichen was available in old growth at the abundance reported by Stevenson (1978) and Rochelle (1980), then the amount of digestible forage in both habitats becomes similar.

Apparently the pole-sapling stands used by deer in this study had sufficient forage to meet the needs of deer during short periods of snow accumulation (assuming they adopt a diet generalist strategy). That conclusion, although speculative, would explain the seeming success of resident pole-sapling deer in dealing with inclement weather during winter. The reduction of home range size, the reduction of distance moved between successive 2-hourly relocations, and the lowering of activity levels would support the assumption that deer shift away from a diet specialist, searching strategy, to a more general foraging behaviour during inclement weather.

Aside from the strategies chosen by deer during mild winters, it is important to note their relative inflexibility once the behaviours are adopted (Dasmann and Taber 1956; Schoen and Kirchhoff 1985). In a location such as Vancouver Island where weather patterns are inconsistent

---

[11] Nyberg et al. [1987]. In preparation.
[12] Nyberg et al. [1987]. In preparation.

(Fig. 3; Section 1), it seems logical that the composition of local (watershed-based) populations of deer could shift, gaining greater proportions of resident animals during periods of mild winter weather (Section 2.3). This trend would be strengthened by a long winter severity cycle and by forest harvesting practices that juxtapose abundant summer food with winter shelter. That hypothesis is carried further by the anticipation that resident deer would be least able to cope with severe winter weather, since they appear to be least familiar with the surroundings outside their home ranges and, at least in this study location, tend to locate in areas with few habitat choices.

## 4 SUMMARY AND CONCLUSIONS

Four important aspects of this study should be noted in interpreting the main conclusions:

1. The study was conducted through a series of mild winters, compared to the Vancouver Island average (Fig. 3).
2. Historic forest harvesting in the study area likely influenced seasonal movement behaviour through the establishment of low elevation summer habitat (Fig. 2).
3. The sample of radio-collared deer was likely biased toward resident deer that used pole-sapling habitat because of differential abundance of habitat types near roads.
4. The second-growth habitats studied were pole-sapling stage, with crowns that have only recently closed and that still have an abundant supply of rooted forage.[13]

---

[13] Nyberg *et al.* [1987]. In preparation.

Our main conclusions are summarized below:

1. Three types of seasonal movement behaviours were observed (Section 2.2.2):
   i. obligate migrators - move seasonally with little response to weather conditions;
   ii. facultative migrators - move in response to inclement weather (snow) and return upon amelioration of those conditions (melt);
   iii. non-migratory residents - did not move seasonally.

2. The proportion of resident animals in our sample of radio-collared deer was high (50%) relative to other studies of coastal black-tailed deer (Section 2.3).

3. Migratory deer moved as much as 15 km between seasonal home ranges, and resident deer typically moved less than 1 km from their core home range centre (Section 2.2.2).

4. During winter, the radio-collared deer generally selected southerly aspects and lower elevations (Section 2.2.4).

5. Excluding migration routes, migratory deer had much larger home ranges than resident deer (Section 2.2.3).

6. Most migratory deer used all forested habitats, whereas most resident deer used only pole-sapling stands (Section 2.2.4).

7. Obligate migrators and resident deer used all habitats available to them within the boundaries of their seasonal home ranges and did not seek alternative habitats or new areas during severe winter weather. Facultative migrators showed strong site fidelity for those areas that were traditionally used during inclement weather (Section 3.2.4).

8. When deer moved to the closest forest habitat during inclement weather, there was usually a 50% reduction in home range size (Section 3.2.3).

9. Deer reduced their mobility by 13-40% (indexed by distance between successive 2-hourly locations) during cold-snow weather (Section 3.2.5).

10. Although there was great individual variety of habitat use strategies and seasonal movement behaviours among the sampled deer, all animals exhibited strong seasonal site fidelity to particular locations and behaviours (Sections 2.2.2, 2.3, and 3.3).

11. Because of the mild winter weather conditions prevalent during the study, there are no data to suggest which winter habitat use strategy would be most successful during prolonged severe winter conditions (Section 3.3).

12. Individual deer are expected to be relatively inflexible in their responses to habitat changes; residents are the least capable of coping with catastrophe. Habitat management and winter weather patterns are postulated as key factors in determining the proportion of each behaviour type in watershed-based populations (Section 3.3).

The potential bias in the data aside, the most striking results of this study are those illustrating the great fidelity by individual deer to particular areas, and to the particular behaviours that they either learned or adopted. Much of the variation can be grouped by behaviour class, provided sufficient habitat use or seasonal movement data are available. Because different habitat use groups were observed in the absence of any data suggesting nutritional advantage, no conclusion can be made about specific forest attributes preferred by deer (on a population basis). Based on the variety of strategies we observed, it is clear that site and behaviour fidelity could override the selection for habitat quality. That seems particularly logical during times when populations are below carrying

capacity, during mild winters, or both since variation in acceptable (as opposed to best) strategies would be greatest.

Study designs aimed at distinguishing net benefits in habitat use between habitat use groups require more information than was attempted during this study. A detailed assessment of deer movement and foraging behaviour sampled in different habitats over a range of snow accumulations would help to identify potential differences in net energy acquisition and/or changes in foraging behaviour.[14] Such a study could be even more meaningful if it were done with a study of deer physiology, as well as with population studies.[15]

The results of this study indicate that further analysis is necessay to investigate: the combined effects of forest harvesting patterns on the relative proportions of deer behaviour types found in a watershed; the comparative resiliancy of these behaviour types to winter severity; and the potential impact of winter severity cycles on watershed-based populations.

This study (in co-operation with others) was initiated to help the MOFL decide the future of specific old-growth winter habitat, and to help the MOEP make recommendations about the improvement of specific second-growth winter habitat (Section 1; Nyberg et al. 1986). Due to the lack of severe winter weather throughout this study, we can only add a few recommendations to those of Nyberg et al. (1986). First, based on the observations here, we concur that research into silvicultural manipulations to create winter range in young managed stands is one of the best options to investigate; particularly in those areas that have no or little old-growth habitat remaining. In other areas, the influence of weather cycles and habitat manipulation on the habitat use behaviour must be researched further before deer managers can assess where, how many, and what size of areas to manage for winter habitat.

---

[14] Page and McNay. [1987]. In preparation.
[15] Hovey, F.W. and F.L. Bunnell. [1987]. Limitations of condition indices as measures of habitat quality. J. Wildl. Manage. (Submitted).

## 5 LITERATURE CITED

Alldredge, J.R. and J.T. Ratti. 1986. Comparison of some statistical techniques for the analysis of resource selection. J. Wildl. Manage. 50(1): 157-165.

Atkinson, K. and D. Janz. 1986. Effect of wolf control on black-tailed deer in the Nimpkish Valley on Vancouver Island. B.C. Min. Environ. WR-19. Victoria, B.C. 31 p.

B. C. Ministry of Forests and Ministry of Environment. 1982. Problem analysis: old-growth and ungulates of northern Vancouver Island. A discussion paper. B.C. Min. For., Strategic Studies Branch, Victoria, B.C. 11 p.

B.C. Ministry of Forests. 1984. Forest and range resource analysis - 1984. B.C. Min. For., Strategic Studies Branch, Victoria, B.C. 379 p.

_____. 1985. Ministry of Forests annual report - 1984-1985. For. Serv., Victoria, B.C. 59 p.

Brown, E.R. 1961. The black-tailed deer of western Washington. Wash. State Game Dep., Biolog. Bull. No. 13. 124 p.

Bunnell, F.L. 1985. Forestry and black-tailed deer: conflicts, crises, or cooperation. For. Chron. 61(2): 180-184.

Bunnell, F.L. and G.W. Jones. 1984. Black-tailed deer and old-growth forests: a synthesis. In Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (technical editors). Bookmasters, Ashland, Ohio, pp. 411-420.

Clements, C. 1985. Ecosystematic units of the south Nanaimo River deer study area. Map research and production for the Integrated Wildlife - Intensive Forestry Research program. B.C. Min. Environ. and Min. For., Victoria, B.C.

Clover, M. 1956. Single-gate deer trap. Calif. Fish and Game 42(3): 199-201.

Cowan, I.M. 1945. The ecological relationships of the food of the Columbian black-tailed deer, Odocoileus hemionus columbianus (Richardson), in the coast forest region of southern Vancouver Island, British Columbia. Ecol. Monogr. 15(2): 111-139.

Dasmann, R.F. and R.D. Taber. 1956. Behavior of Columbian black-tailed deer with reference to population ecology. J. Mammal. 37: 143-164.

Edwards, R.Y. 1956. Snow depths and ungulate abundance in the mountains of western Canada. J. Wildl. Manage. 20: 159-168.

Gillingham, M.P. 1985. Foraging behaviour of captive black-tailed deer (Odocoileus hemionus columbianus). Ph.d. thesis. Univ. B.C., Vancouver, B.C. 78 p.

Harestad, A.S. 1979. Seasonal movements of black-tailed deer on northern Vancouver Island. B.C. Min. Environ., Fish and Wildl. Rep. No. R-3. 98 p.

_____. 1981. Computer analysis of home range data. B.C. Min. Environ., Wildl. Bull. No. B-11. 25 p.

Hatter, I.W. 1982. Predator-ungulate relationships in second growth forests on Vancouver Island. Problem Analysis. B.C. Min. Environ. and Min. For., Research. IWIFR-5. Victoria, B.C. 54 p.

_____. 1983. Effects of wolf predation on recruitment of black-tailed deer on northeastern Vancouver Island. M.Sc. thesis. Univ. Idaho. Moscow, Idaho. 156 p.

Hayes, W.L. and R.L. Winkler. 1970. Statistics: probability, inference and decision. Vol. 1. Holt, Rinehard and Winston, New York, N.Y. 650 p. (Cited by Neu et al. 1974.)

Heisey, D.M. and T.K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. J. Wildl. Manage. 49(3): 668-674.

Hines, W. W. 1975. Black-tailed deer behavior and population dynamics in the Tillamook Burn, Oregon. Oreg. Wildl. Commission Wildl. Rep. 5. 31 p.

Hupp, J. W. and J. T. Ratti. 1983. A test of radio telemetry triangulation accuracy in heterogenous environments. Proc. Int. Wildl. Biotelem. Conf. 4:31-46.

Janz, D., K. Brunt, and J. Youds. 1980. Vancouver Island Roosevelt elk forestry interactions: problem analysis. B.C. Min. Environ. and Min. For., Research. IWIFR-11. Victoria, B.C. 36 p.

Janz, D. and I. Hatter. 1986. A rationale for wolf control in the management of the Vancouver Island predator-ungulate system. B.C. Min. Environ., Wildl. Bull. No. B-45. 35 p.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61(1): 65-71.

Jones, G.W. 1974. Influences of forest development on black-tailed deer range on Vancouver Island. In Symp. on Wildlife and Forest Management in the Pacific Northwest. Corvallis, Oreg., Sept. 1973, pp. 139-148

_____. 1975. Aspects of the winter ecology of black-tailed deer (Odocoileus hemionus columbianus Richardson) on northern Vancouver Island. M.Sc. thesis. Univ. of B. C., Vancouver, B.C. 78 p.

Jones, G.W. and B. Mason. 1983. Relationships among wolves, hunting, and population trends of the black-tailed deer in the Nimpkish Valley on Vancouver Island. B.C. Min. Environ., Fish and Wildl. Rep. No. R-7, Victoria, B.C. 25 p.

Klein, D.R. and S.T. Olson. 1960. Natural mortality patterns of deer in southeast Alaska. J. Wildl. Manage. 24(1): 80-88.

Klinka, K., R. Green, P. Courtin, and F. Nuszdorfer. 1984. Site diagnosis, tree species selection, and slashburning guidelines for the Vancouver Forest Region. B.C. Min. For., Land Manage. Rep. No. 25. Victoria, B.C. 180 p.

Krueger, W. 1972. Evaluating animal forage preference. J. Range. Manage. 25: 471-475

Leckenby, D.A. and A.W. Adams. 1986. A weather severity index on a mule deer winter range. J. Range Manage. 39(3): 244-248.

Loft, E.R., J.W. Menke, and T.S. Burton. 1984. Seasonal movements and summer habitats of female black-tailed deer. J. Wildl. Manage. 48(4): 1317-1325.

McCullough, D.R. 1964. Relationship of weather to migratory movements of black-tailed deer. Ecology 45: 249-256.

McDaniels Research Ltd. 1980. An evaluation of wildlife enhancement through silvicultural changes in the Sayward Forest. Rep. to B.C. Min. For., Strategic Studies Branch, Victoria, B.C. 53 p.

McNay, R.S. and R. Davies. 1985. Interactions between black-tailed deer and intensive forest management: a problem analysis. B.C. Min. Environ. and Min. For., Research IWIFR-22. Victoria, B.C. 110 p.

McNay, R.S., R.E. Page, and A. Campbell. [1987]. Application of expert-based decision models to promote integrated management of forests. Trans. N. Am. Wildl. Nat. Resourc. Conf. 52. (In press)

Neu, C.W., C.R. Byers, and J. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38(3): 541-545

Nudds, T.D. 1980. Forage "preference": theoretical considerations of diet selection by deer. J. Wildl. Manage. 44(3): 735-740.

Nyberg, J.B. 1985. Intensive forestry effects on Vancouver Island deer and elk habitats: problem analysis. B.C. Min. Environ. and Min. For., Research IWIFR-16. Victoria, B.C. 70 p.

Nyberg, J.B., F.L. Bunnell, D.W. Janz, and R.M. Ellis. 1986. Managing young forests as black-tailed deer winter ranges. B.C. Min. For., Land Manage. Rep. No. 37. Victoria, B.C. 49 p.

Nyberg, J.B., D. Doyle, and L. Peterson. 1985. Deer movements and habitat use during winter: working plan. B.C. Min. Environ. and Min. For., Research IWIFR-18. Victoria, B.C. 81 p.

Ozoga, J. and L. Gysel. 1972. Response of white-tailed deer to winter weather. J. Wildl. Manage. 36: 892-896.

Page, R. 1982. Technological concerns in the use of radio telemetry for animal habitat identification. B.C. Min. For., Res. Branch. WHR-2. Victoria, B.C. 40 p.

Potvin, F., J. Huot, and F. Duchesneau. 1981. Deer mortality in the Pohenegamook wintering area, Quebec. Can. Field-Nat. 95(1): 80-84.

Reid, R. 1985a. The value and characteristics of resident hunting. B.C. Min. Environ., Wildl. Branch, Victoria, B.C. 153 p.

_____. 1985b. The value and characteristics of non-resident hunting. B.C. Min. Environ., Wildl. Branch, Victoria, B.C. 183 p.

Reid, R., M. Stone, and F. Rothman. 1985. Report of the British Columbia survey of wildlife activities for 1983. Rep. to B.C. Min. Environ., Wildl. Branch, Victoria, B.C. 152 p.

Robinson, D.J. 1956. Preliminary studies upon the effects of logged over areas on the quality and size of deer populations on Vancouver Island. Presented at the annual meeting of the Northwest Section of The Wildlife Society. Seattle, Wash. 8 p.

Rochelle, J.A. 1980. Mature forests, litterfall, and patterns of forage equality as factors in the nutrition of black-tailed deer on Vancouver Island. Ph.D. thesis. Univ. B. C., Vancouver, B.C. 295 p.

Romesburg, H.C. 1981. Wildlife science: gaining reliable information. J. Wildl. Manage. 45: 293-313

SAS Institute Inc. 1985. SAS user's guide: Statistics. 5th ed. SAS Institute Inc., Cary, N.C. 956 p.

Saver, P.R. and C.W. Severinghaus. 1983. Relationship of degree and composition of winter mortality of deer, as indicated by strip surveys, to severity of the winter. N.Y. Fish and Game J. 30(2): 173-181.

Schoen, J.W. and M.D. Kirchhoff. 1985. Seasonal distribution and home-range patterns of Sitka black-tailed deer on Admiralty Island, Southeast Alaska. J. Wildl. Manage. 49(1): 96-103.

Smith, I.D. 1969. 13-year deer study. Western Fish and Game, January. 4 p.

Stevenson, S.K. 1978. Distribution and abundance of arboreal lichens and their use as forage by black-tailed deer. M.Sc. thesis. Univ. B.C., Vancouver, B.C. 148 p.

Swihart, R. and N. Slade. 1985. Influence of sampling interval on estimates of home range size. J. Wildl. Manage. 49(4): 1019-1025.

Telfer, E.S. 1978. Cervid distribution, browse and snow cover in Alberta. J. Wildl. Manage. 42(2): 352-361.

APPENDIX 1. Immobilization of black-tailed deer

## Introduction

Because radio telemetry was to be tested as a method of determining habitat use (Section 2) by deer in the study area, the development of live-capture techniques for collaring deer with radio transmitters was a priority in the 1st year of the project. Previous attempts to capture free-ranging Vancouver Island black-tailed deer (Harestad 1979) had been successful using a muscle relaxant drug, succinylcoline chloride (Anectine), administered by a dart fired from a gun. Harestad (1979) also captured deer in a single-gate box-trap (Clover 1956). Ministry of Environment and Parks staff (Region 1) had immobilized a few deer with a combination of Ketamine and Rompun (50:50), but found it put animals down for excessively long times (H.Langin, pers. comm., Dec. 1981). Our objective was to evaluate these techniques while attempting to radio collar a minimum of 20 female deer in the study area.

## Methods

Powdered Anectine was administered in 6-13 mg Pneu darts (Pneu Dart, Inc. Williamsport, P.A.) fired from a Palmer Capchur gun. Darting of deer was accomplished either by stalking them on foot during daylight hours (usually when there was sufficient snow to track animals) or by spotlighting them from a vehicle in open clearcuts during nights when there was no snowpack.

Clover traps were placed in areas of concentrated deer use and baited with both native forages (red huckleberry, red cedar, arboreal lichens) and a wide variety of non-native forages (commercial alfalfa mixtures, apples, garden variety roses and various members of the cabbage family). Traps were checked daily.

## Results

A summary of attempted immobilization using Anectine is provided in Table A1.1. Forty-seven deer were successfully immobilized with dosages ranging from 5 to 13 mg. There were nine known mortalities. Reaction to the

TABLE A1.1. Summary of immobilization of black-tailed deer with succinylcoline chloride (Anectine)

| | | |
|---|---|---|
| No. of deer darted: 88 | | |
| No. of deer immobilized and found: 47 (53.4%) | | |
| No. of known mortalities: 9 (10.2%) | | |
| Average dosage to immobilize: | 9.3 mg (n = 47) | Low: 5 mg<br>High: 13 mg |
| | modal dosage: 11 mg | |
| Average time to immobilization: | 5.7 min. (n = 38[a]) | Low = 10 secs.<br>High = 12 min. |
| Average time to full recovery: | 55.9 min. (n = 37[a]) | Low = 9.5 min.<br>High = 158 min. |

[a] Only samples where time could be accurately estimated were included in the calculation.

drug was variable, suggesting a narrow tolerance range as well as individual differences among deer of similar sex and size. Location of dart impact and the passive delivery system of the powdered Pneu dart probably added to the variation. Attempts to immobilize previously radio-collared animals resulted in one success out of five attempts using 11 mg of Anectine on deer of the same approximate size and sex (4- to 6-year-old females).

A comparison of capture techniques for the 1st year of study (1981-1982) is presented in Table A1.2. Spotlighting proved to be the most efficient method of immobilization, as illustrated by the greater percentage of deer that were immobilized and located per hit (51.7 versus 25.8% for the daylight method).

TABLE A1.2. Efficiency of immobilization techniques

| Technique | Effort (person hr) (trap nights) | Success | Known mortalities | Attempts |
|---|---|---|---|---|
| Daylight hunt | 218 | 8 | 2 | 31 |
| Night hunt | 328 | 15 | 1 | 29 |
| Clover trap | 66 | 5 | 0 | 7 |

Clover trapping resulted in five successfully captured deer (two others broke out of the traps) in 66 trap-nights. Clover traps were used successfully when there was snow on the ground and when native forages, particularly red cedar (Thuja plicata) and arboreal lichens (Usnea spp.), were used as bait.

Discussion

The greater efficiency of capturing deer using lights and vehicles at night, rather than on foot during daylight hours, appears to be related to our observation that deer retreat further to cover during daylight hours, thereby reducing the chance of finding an immobilized animal.

Clover trapping was only effective using native forages during restrictive snow conditions. If there had been a more consistent snowpack, reducing forage availability for a greater length of time, the deer might have been more susceptible to clover trapping.

Although the effects of Anectine were extremely variable and caused mortalities 10% of the time, the range (50-70 m), accuracy (flatter trajectory than larger and heavier Palmer darts), and light impact of the Pneu dart made it the most successful of the techniques tried.

LITERATURE CITED

Clover, M. 1956. Single-gate deer trap. Calif. Fish and Game 42(3): 199-201.

Harestad, A.S. 1979. Seasonal movements of black-tailed deer on northern Vancouver Island. B.C. Min. Environ., Fish and Wildl. Rep. No. R-3. 98 pp.

APPENDIX 2. Summary of telemetry samples and status of radio-collared deer

| Deer I.D. # | Seasonal[a] movement behaviour | Habitat use group[c] | Date collared (yr/mo/dy) | Date dead (yr/mo/dy) | Cause[b] of death | Collar-days old (To 86/03/30) | Telemetry samples Winter Reg. | Winter Iten. | Summer | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 07801 | R | A | 85/10/02 | - | - | 180 | 18 | 24 | 2 | 44 |
| 09101 | F | D | 85/01/29 | - | - | 425 | 32 | 62 | 7 | 101 |
| 13201 | F | A | 84/01/04 | 85/03/03 | Wolf | 355 | 21 | 34 | 12 | 67 |
| 13301 | F | C | 83/07/26 | 84/11/17 | Shot (LH) | 481 | 17 | 33 | 24 | 74 |
| 13401 | R | C | 84/02/01 | 85/01/20 | Wolf | 355 | 21 | 34 | 12 | 67 |
| 13501 | R | C | 83/10/16 | - | - | 897 | 62 | 93 | 24 | 179 |
| 13601 | R | A | 84/02/07 | 86/06/09 | Wolf | 853 | 51 | 24 | 16 | 91 |
| 15001 | O | C | 82/01/25 | - | - | 1526 | 105 | 174 | 55 | 334 |
| 15101 | * | * | 82/01/22 | 82/05/20 | Wolf | 119 | 3 | - | 7 | 10 |
| 15102 | R | A | 82/06/05 | - | - | 1395 | 90 | 221 | 48 | 359 |
| 15201 | F | C | 82/05/15 | - | - | 1416 | 93 | 194 | 63 | 350 |
| 15401 | F | C | 82/03/14 | - | - | 1478 | 59 | 37 | 75 | 171 |
| 15501 | * | * | 82/01/24 | 82/11/10 | Shot (N) | 291 | 7 | - | 32 | 39 |
| 15502 | R | A | 83/04/13 | 85/09/28 | Shot (P) | 900 | 39 | 114 | 44 | 197 |
| 15601 | * | * | 82/02/12 | 82/10/06 | Wolf | 237 | 4 | - | 28 | 32 |
| 15602 | R | A | 82/10/07 | 83/11/08 | Shot (LH) | 398 | 23 | 71 | 21 | 115 |
| 15701 | R | B | 82/08/03 | - | - | 1336 | 76 | 152 | 50 | 278 |
| 15801 | * | * | 82/02/02 | 82/11/04 | Unknown | 276 | 4 | - | 30 | 34 |
| 15901 | * | * | 82/04/16 | 82/07/20 | Wolf | 96 | - | - | 15 | 15 |
| 15902 | R | B | 82/07/26 | 86/06/02 | Cougar | 827 | 80 | 124 | 53 | 257 |
| 16101 | * | * | 82/03/05 | 82/04/04 | Starvation | 31 | 1 | - | - | 1 |
| 16102 | F | D | 82/04/06 | 84/12/17 | Unknown | 987 | 46 | 92 | 64 | 202 |
| 16301 | F | A | 82/06/16 | 84/05/08 | Accident | 782 | 43 | 30 | 35 | 108 |
| 16401 | F | D | 82/02/23 | 83/08/26 | Unknown | 550 | 33 | - | 31 | 64 |
| 16601 | * | * | 82/02/03 | 82/04/05 | Starvation | 62 | 2 | - | - | 2 |
| 16602 | O | C | 83/05/17 | - | - | 1049 | 6 | - | 33 | 39 |
| 16901 | * | * | 82/02/26 | 82/04/04 | Starvation | 38 | 3 | - | - | 3 |
| 17101 | F | B | 82/04/02 | - | - | 1459 | 77 | 43 | 68 | 188 |
| 17301 | F | B | 82/08/01 | 85/01/07 | Cougar | 891 | 46 | 120 | 56 | 222 |
| 17401 | F | B | 82/05/28 | - | - | 1403 | 86 | 180 | 62 | 328 |
| 17501 | R | C | 82/07/15 | 86/09/05 | Missing | 1455 | 74 | 40 | 52 | 170 |
| 17601 | R | A | 82/07/30 | 83/11/15 | Unknown | 474 | 24 | 93 | 36 | 153 |
| 17701 | R | C | 82/04/15 | - | - | 1446 | 72 | 88 | 68 | 228 |
| 17801/07701 | R | A | 82/03/02 | - | - | 1490 | 88 | 213 | 80 | 381 |
| 17901 | O | D | 82/03/31 | 86/10/08 | - | 1456 | 80 | 108 | 74 | 262 |
| 18001 | R | B | 82/05/23 | 84/06/04 | Wolf | 744 | 36 | - | 42 | 78 |
| Total | | | | | | 28228 | 1528 | 2417 | 1319 | 5264 |

a - * = Unknown, R = resident, F = facultative migrator, O = obligate migrator.
b - Shot (LH) = licenced hunter, Shot (N) = native, Shot (P) = poached.
c - * = Unknown, A = early successional and pole-sapling habitats, B = early successional and pole-sapling + mixed pole-sapling/old-growth habitats, C = early successional + pole-sapling + old-growth habitats, and D = all habitats.

APPENDIX 3. A comparison of pellet group sampling and radio telemetry as measures of habitat use by deer

## Introduction

The objective of this pilot project was to evaluate radio telemetry and pellet group counts as measures of winter habitat use. This assumes that radio telemetry can accurately measure habitat use from a representative subsample of a deer population, and that pellet group sampling is an index of habitat use by the total population.

## Methods

Permanent pellet group plots were established in two habitat types: old-growth timber and adjacent pole-sapling stands (22 years old). For site descriptions see Nyberg et al. (1985; [p. 17, J-11 winter habitat]). Transects were oriented upslope using four 9.3 $m^2$ (100 sq. ft.) circular plots, every 61 m (200 ft.). Pellet groups were counted and cleared in spring and fall to isolate winter use. Analysis of pellet group data was based on maximum likelihood estimation of the negative binomial distribution (after White and Eberhardt 1980).

Radio telemetry data were collected weekly during the winters of 1982/83 and 1983/84 (for details on telemetry methods see Section 2). Only animals whose home ranges overlapped the pellet group transects were used in the comparisons (a sample of four each year - deer No. 50, No. 52, No. 35, No. 76). The data were summarized as the percent of locations in the respective habitat types under consideration.

## Results

Analysis of variance of the pellet group data showed no significant differences in the mean number of pellet groups or their distribution (clumpiness or K) within habitat types, so data were pooled at that level of analysis.

Next we compared old-growth timber and pole-sapling stands within years. All means of the number of pellet groups in old-growth timber were significantly higher ($p = .05$) than adjacent pole-sapling stands, but the K values were usually similar. Finally, we compared old-growth timber and adjacent pole-sapling stands for pooled years and found similar results. Thus, analysis of pellet group data showed that deer use of old-growth timber was greater than their use of young (20-year-old) pole-sapling stands, even in mild winters with little or no snow accumulation.

Radio telemetry data are presented in Figure A3.1. In both 1983 and 1984 greatest use occurred in the pole-sapling stands (66 vs 9% in 1983 and 48.5 vs 12.0% in 1984).

Results are summarized in Figure 1. The two methods show opposite results with respect to use of stand types.

Discussion

The comparison of use is based on small sample sizes, but assuming the validity of radio telemetry as a measure of habitat use and that our radio-collared animals were representative of the population, it raises serious doubts about pellet group data as an index to habitat use. Habitat use interpretations from pellet group data can be affected by differences in defecation and deterioration rates; observability bias, due to understory vegetation; and observer bias (Stordeur 1984). Additionally, pellet group counts may relate better to foraging and movement behaviour than to actual proportion of time spent in various habitats. Track counts on the same sites in 1985 showed a strong selection for the old-growth habitat type.[1] This may again relate more to foraging and movement than total use. Further, pellet group sampling generally masked variations in winter conditions over a 3-4 month period, -- and would therefore not have furthered our understanding of how a deer's winter habitat selection changes in response to specific conditions (i.e., snow events or changes in forage availability or quality) -- the pellet group sampling scheme was discontinued.

---

[1] Nyberg, J.B., L. Peterson, L.A. Stordeur, and R.S. McNay. [1987]. Deer use of old-growth and immature forests following snowfalls on southern Vancouver Island. B.C. Min. For. Lands, Victoria, B.C. In preparation.

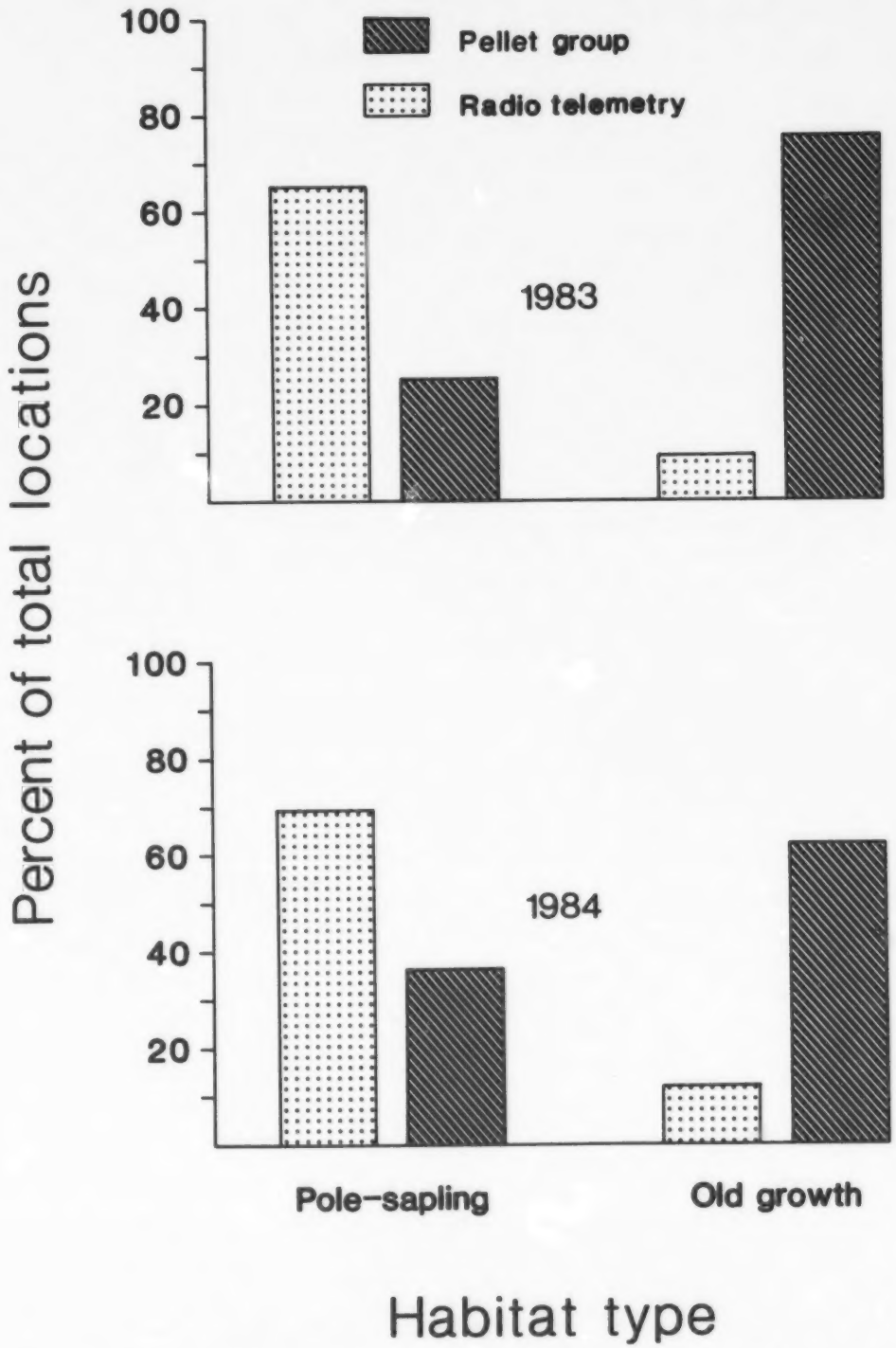


FIGURE A3.1. Comparitive use of winter habitats as depicted by pellet group data and by radio-telemetry.

The data we collected are insufficient by themselves, however, to indicate which method is best for estimating habitat use by the population. The radio-telemetry data were based on a small, possibly unrepresentative sample with infrequent relocations (Section 2), and are subject to their own set of biases. A much larger, more rigorous sampling scheme would be needed to test the relative merits of each technique.

LITERATURE CITED

Nyberg, J.B., D. Doyle, and L. Peterson. 1985. Deer movements and habitat use during winter: working plan. B.C. Min. Environ. and Min. For., Research. IWIFR-18. Victoria, B.C. 81 p.

Stordeur, L. (editor) 1984. Proceedings of a seminar on ungulate pellet group sampling and data analysis techniques. B.C. Min. For., Res. Branch. WHR-7. Victoria, B.C. 98 p.

White, G.C. and L.E. Eberhardt. 1980. Statistical analysis of deer and elk pellet group data. J. Wildl. Manage. 44(1): 121-131.

APPENDIX 4. Winter diet determination from rumen and fecal analyses

## Introduction

Knowledge of deer diets could enhance our understanding of habitat selection as it related to forage availability during winter. The main objectives of this study were to compare diets determined from rumen and fecal analysis and to compare during periods of snow accumulation and ablation, the diets of deer living in old-growth stands to those living in pole-sapling stands.

## Methods

Animals were stalked on foot and shot to allow collection of rumen contents. The rumen and intestinal tract of each animal was removed and approximately 1 L of hand-mixed rumen content and 20 pellets from the intestine were bagged and frozen. Objectives called for two animals to be collected in each of two old-growth winter habitats (henceforth referred to as Dunsmuir and Jump old-growth winter habitats) and one pole-sapling winter habitat for a total of six animals. Due to problems stalking the animals, only four were collected (collection followed the February 12, 1985 snow/vegetation/track sampling).[1] Two deer were taken from the Jump old-growth winter habitat, one from the Dunsmuir old-growth winter habitat, and one from the Dunsmuir pole-sapling winter habitat. A composite sample of fresh pellet groups (n=10) was collected in the respective winter habitats at the same time. Three pellets from each of the 10 groups formed the composite sample. Collections were done when greater than 30 cm of snow had accumulated in the open for 5 days. Seven days after snow ablation had occurred, fresh pellet groups were again collected for a composite sample. In the absence of a snowpack, pellet group freshness was determined by colour, texture, and sheen.

Rumen and fecal fragment analyses were performed by the Wildlife Habitat Laboratory, Washington State University, Pullman, Washington.

---

[1] Nyberg, J.B., L. Peterson, L.A. Stordeur, and R.S. McNay. [1987]. Deer use of old-growth and immature forests following snowfalls on southern Vancouver Island. B.C. Min. For., Victoria, B.C. In preparation.

Results

Diet compositions by plant species are given in Table A4.1. The major difference between samples from old-growth stands and those from pole-sapling stands was the lack of lichens in the latter, which was expected because of their low availability in young stands.

A comparison of diets by major forage classes between rumens and fecal material from the same animals are summarized in Table A4.2. In samples from the old-growth stand, fecal fragment analysis overestimated the shrub component of the diet and underestimated the lichen component (compared to the rumen contents from the same animals). The shrub component in the three rumen samples collected in the old-growth stand totalled 28, 9, and 15%; the fecal samples were 46, 41, and 31%, respectively. Lichens in the same rumens totalled 42, 32, and 50%, respectively, while the fecal samples were 3, 6 and 14%. The diet composition from the pole-sapling winter habitat was consistently represented by both the rumen and fecal samples.

Fecal analysis was used for a comparison of diets from the period of moderate snowpack and the subsequent melt (Table A4.3). After the melt, samples from the old-growth winter habitats showed an increase in the use of ferns (especially Blechum spicant, deer fern) and grasses, and a decrease in the use of conifers and shrubs. Because of the problems with lichen composition in fecal material, little can be inferred about the use of arboreal lichens in snow versus no-snow conditions, except that there was no evidence that lichen use changed after snow melt. In the pole-sapling winter habitat, the pattern was similar with increased use of ferns and grasses and decreased use of shrubs after snow melt. There was also a slight increase in the use of conifers. This may have been the result of access to young conifers in the clearcuts where more of the current year's annual growth was available to the deer.

Discussion

Diet determination from fecal and rumen analyses can be seriously confounded by the differential digestibility of forages (Gaare et al. 1977;

TABLE A4.1. Deer diet composition by species as determined from rumen content and fecal analyses

| Species | Jump old growth | | | | | | Dunsmuir old growth | | | | Dunsmuir second growth | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yearling | | Mature | | Composite fecal | | Mature | | Composite fecal | | Yearling | | Composite fecal | |
| | rumen | fecal | rumen | fecal | snow | no snow | rumen | fecal | snow | no snow | rumen | fecal | snow | no snow |
| Tsuga heterophylla | 2.0 | 5.9 | 1.9 | 4.5 | 5.6 | 1.1 | 2.9 | 1.3 | 2.5 | 1.5 | .7 | 2.0 | 1.7 | 1.2 |
| Thuja plicata | 16.1 | 21.9 | 14.4 | 20.2 | 16.2 | 15.3 | 10.3 | 17.7 | 28.5 | 20.1 | 9.2 | 14.1 | 14.8 | 14.3 |
| Pseudotsuga menziesii | 34.5 | 21.6 | 14.0 | 24.8 | 33.5 | 19.3 | 14.3 | 22.9 | 14.2 | 13.4 | 7.0 | 5.0 | 4.2 | 10.0 |
| Abies amabilis | - | - | - | - | - | - | - | .6 | - | 1.0 | - | - | - | - |
| Bark | 4.9 | 2.6 | 1.8 | 1.9 | .2 | - | .2 | 3.2 | 1.5 | .6 | - | 1.1 | - | - |
| Total | 57.5 | 52.0 | 32.1 | 51.4 | 55.5 | 35.5 | 27.7 | 45.7 | 46.7 | 36.6 | 16.9 | 22.2 | 20.7 | 25.5 |
| Gaultheria shallon | 6.2 | 20.3 | 15.0 | 23.3 | 32.0 | 32.6 | 27.2 | 26.0 | 33.4 | 28.8 | 67.5 | 64.8 | 48.5 | 41.1 |
| Vaccinium spp. | 3.5 | 17.6 | .7 | .9 | 4.1 | 2.6 | .7 | 14.0 | 4.1 | 1.7 | 1.7 | 2.0 | 12.6 | 3.3 |
| Rubus leucodermis | - | 1.5 | - | 6.2 | 3.0 | - | - | 2.5 | 2.9 | .1 | .2 | 2.5 | 1.7 | .7 |
| Sambucus racemosa | - | - | - | - | - | 1.3 | - | - | - | - | - | - | - | - |
| Rubus spectabilis | - | - | - | - | - | - | - | - | - | 2.7 | - | - | - | - |
| Salix spp. | - | - | - | - | - | .2 | .4 | .2 | .8 | - | - | - | .4 | 1.3 |
| Alnus rubus | - | - | - | - | - | 1.3 | - | .2 | - | - | 1.7 | - | 1.4 | - |
| Ribes bracteosum | - | - | - | - | - | - | - | .2 | - | - | - | - | - | 1.1 |
| Prunus emarginata | - | .5 | - | - | - | - | - | - | - | - | - | .8 | - | - |
| Symphoricarpos albus | - | - | - | - | - | - | - | - | - | 1.1 | - | - | - | - |
| Menziesia ferruginea | - | - | - | - | - | - | - | - | - | .1 | - | - | - | - |
| Unknown | - | 1.2 | - | 1.2 | 1.2 | - | - | 2.7 | - | .5 | - | - | - | .5 |
| Total | 9.7 | 41.5 | 15.7 | 31.6 | 40.3 | 37.7 | 28.3 | 46.5 | 41.2 | 35.7 | 71.7 | 70.1 | 64.6 | 50.9 |
| Lichens | 32.8 | 6.5 | 50.9 | 14.8 | 1.4 | 2.7 | 42.5 | 3.5 | 1.3 | 5.1 | 4.3 | 2.0 | - | .3 |
| Blechnum spicant | - | - | 1.3 | 2.2 | 2.6 | 4.9 | 1.5 | 2.9 | 6.7 | 18.5 | 2.7 | 4.5 | 10.7 | 16.5 |
| Polystichum munitum | - | - | - | - | .2 | 3.7 | - | .9 | 4.2 | .8 | 2.5 | .9 | 2.9 | 1.9 |
| Athyrium felix - femina | - | - | - | - | - | 1.1 | - | .3 | - | .6 | .8 | - | .6 | .8 |
| Pteridium aquilinum | - | - | - | - | - | - | - | - | - | .4 | - | - | .5 | - |
| Fern rhizome | - | - | - | - | - | - | - | - | - | .8 | - | - | - | - |
| Total | - | - | 1.3 | 2.2 | 2.8 | 9.7 | 1.5 | 4.1 | 10.8 | 20.9 | 6.0 | 5.4 | 14.7 | 19.2 |
| Poaceae | - | - | - | - | - | 11.2 | - | - | - | .5 | - | - | - | 2.6 |
| Cyperaceae | - | - | - | - | - | 2.8 | - | - | - | - | - | - | - | 1.5 |
| Total | - | - | - | - | - | 14.0 | - | - | - | .5 | - | - | - | 4.1 |
| Verbascum thapsis | - | - | - | - | - | .2 | - | - | - | - | - | - | - | - |
| Total | - | - | - | - | - | .2 | - | - | - | - | - | - | - | - |
| Lycopodium spp. | - | - | - | - | - | - | - | - | - | .5 | - | - | - | - |

TABLE A4.2. A comparison of winter diets from rumens and fecal samples from old-growth winter ranges and second-growth winter ranges, with 60-100 cm of snow in the open and 20-40 cm under the tree canopies

| | Rumens[a] | Matching fecal[b] | Composite fecal[c] |
|---|---|---|---|
| Old-growth winter ranges | | | |
| Conifers | 39.1 | 43.1 | 51.1 |
| Shrubs | 17.9 | 39.8 | 41.0 |
| Lichens | 42.0 | 8.2 | 1.3 |
| Ferns | 1.0 | 2.1 | 6.0 |
| Grasses | - | - | - |
| Second-growth winter ranges | | | |
| Conifers | 16.7 | 22.2 | 20.7 |
| Shrubs | 71.7 | 70.1 | 64.6 |
| Lichens | 4.3 | 2.0 | - |
| Ferns | 6.0 | 5.4 | 14.7 |
| Grasses | - | - | - |

[a] n=3 in old growth and n=1 in second growth.
[b] Fecal material from animals sacrificed for rumen samples.
[c] Composite fecal samples were collected on respective ranges directly after rumen samples were taken (n=10 for both old growth and second growth).

TABLE A4.3. A comparison of winter diets (old-growth winter ranges and a second-growth winter range) from fecal analysis collected during snowpack and snow melting conditions

| | Snow[a] | No snow[b] |
|---|---|---|
| Old-growth winter ranges | | |
| Conifers | 51.1 | 36.0 |
| Shrubs | 41.0 | 36.7 |
| Lichens | 1.3 | 3.9 |
| Ferns | 6.0 | 15.3 |
| Grasses | - | 7.3 |
| Second-growth winter ranges | | |
| Conifer | 20.7 | 25.5 |
| Shrubs | 64.6 | 50.7 |
| Lichens | - | - |
| Ferns | 14.7 | 19.2 |
| Grasses | - | 4.1 |

[a] 60-100 cm of snow in open and 20-40 cm under tree canopies.
[b] 0 cm of snow in open and 0-25 cm under tree canopies.

Hanley et al. 1985). Table A4.4 presents the dry matter digestibility and crude protein of the major winter forage species from Rochelle (1980). Lichens have the highest digestibility (78.1%) and salal (the major shrub species) the lowest (26.6%), which may explain the differences between rumen and fecal diet estimates in the old-growth winter habitats. Although there was only one rumen sample from the pole-sapling stand, it was dominated by salal (low digestibility) and compared well with the matching fecal sample. This suggests that it was the level of lichens that confounded the samples collected in the old-growth stands.

Species composition of these winter diets is similar to those found by others for black-tailed deer on Vancouver Island (Cowan 1945; Gates 1968; Jones 1975; Stevenson 1978; Rochelle 1980). Forage availability was measured in the two old-growth winter habitats prior to the rumen and fecal collection.[2] Lichens appeared to be highly preferred as shown by their low availability in the timber and correspondingly high level in the rumens.

TABLE A4.4. Dry matter digestibility and crude protein contents of some important black-tailed deer foods (from Rochelle 1980[a])

| Species | Dry matter digestibility | Crude protein |
|---|---|---|
| Vaccinium spp. | 42.5 | 8.3 |
| Thuja plicata | 50.3 | 4.9 |
| Pseudotsuga menziesii | 47.4 | 5.9 |
| Lichens | 78.1 | 1.8 |
| Tsuga heterophylla | 41.4 | 4.8 |
| Blechnum spicant | 42.0 | 9.0 |
| Gaultheria shallon | 26.6 | 5.0 |
| Polystichum munitum | 24.0 | 8.8 |

[a] Values are for forested habitats during fall and winter.

[2] Nyberg et al. [1987]. In preparation.

However, deer may have altered apparent the availability by eating the bulk of the lichen litterfall before it could be measured (Stevenson 1978). This also infers that lichens were highly selected for as a winter forage in deep snow conditions. More sampling of rumens would be necessary during winter periods with no snow accumulation to determine the contribution of lichens to the overall winter diet in our study area. Levels of lichen consumption may actually increase in mild winters because of less coverage by snow. Jones (1975) found greater levels of arboreal lichens in deer rumens in a mild winter than in a hard winter on northern Vancouver Island.

In the comparison of diets from a period with snow versus one without deer appeared to select some of the more digestible low-growth forages (especially deer fern) once the snow had melted. The use of grasses in the no-snow period may be due to the fact that they began growing immediately following snowmelt. These grasses appeared to be highly selected for, exhibiting a severely grazed form.

These results indicate there is a need to know both the total contribution of lichens to the winter diet of deer and the difference in quality of diets with and without arboreal lichens. This information would suggest the importance of techniques to enhance lichen growth in managed second-growth winter habitats.

LITERATURE CITED

Cowan, I.M. 1945. The ecological relationships of the food of the Columbian black-tailed deer, Odocoileus hemionus columbianus (Richardson), in the coast forest region of southern Vancouver Island, British Columbia. Ecol. Monogr. 15(2): 111-139.

Gaare, E., A. Sorensen, and R.G. White. 1977. Are rumen analyses representative of the diet? Oikos 24: 390-395.

Gates, B.R. 1968. Deer food production in certain seral stages of the coast forest. M.Sc. thesis. Univ. B.C., Vancouver, B.C. 105 p.

Hanley, T.A., D.E. Spalinger, K.A. Hanley, and J.W. Schoen. 1985. Relationships between fecal and rumen analyses for deer diet assessments in Southeastern Alaska. Northwest Sci. 59: 10-16.

Jones, G.W. 1975. Aspects of the winter ecology of black-tailed deer (Odocoileus hemionus columbianus (Richardson)) on northern Vancouver Island. M.Sc. thesis. Univ. B.C., Vancouver, B.C. 78 p.

Rochelle, J.A. 1980. Mature forests, litterfall, and patterns of forage equality as factors in the nutrition of black-tailed deer on Vancourver Island. Ph.D. thesis. Univ. B.C., Vancouver, B.C. 295 p.

Stevenson, S.K. 1978. Distribution and abundance of arboreal lichens and their use as forage by black-tailed deer. M.Sc. thesis. Univ. B.C., Vancouver, B.C. 148 p.

APPENDIX 5. Fecal nitrogen and 2,6 diaminopimelic acid profiles in old-growth and pole-sapling winter habitats of black-tailed deer

Introduction

Arboreal lichens (Usnea and Alectoria) have been identified as major winter dietary items of black-tailed deer on Vancouver Island (Cowan 1945; Gates 1968; Jones 1975; Stevenson 1978; Rochelle 1980; Appendix 4). They are especially important in severe winters when the availability of rooted forage is greatly reduced because of snow cover.

On Vancouver Island, arboreal lichens are only abundant in old-growth forests. Their establishment and growth in second-growth forests (i.e., pole-sapling stands) is a current concern in attempts to manage second-growth stands as winter habitat for black-tailed deer (Stevenson 1985).

The importance of arboreal lichens has been questioned because of their low protein content, yet they are highly digestible and could have a synergistic effect on the overall diet (Rochelle 1980). Since the lack of lichens is the major dietary difference between deer wintering in pole-sapling forests rather than old-growth forests (Appendix 4), it was thought important to assess the impact of the lack of lichens on overall diet quality. Significant relationships between fecal nitrogen and plant crude protein have previously been established for several ungulate species (Hebert 1973; Janz 1983; Leslie and Starkey 1985). Fecal nitrogen has also been shown to have potential as an index of forage quality and animal condition (Leslie and Starkey 1987) although its use as such is not uncontested (Hobbs 1987). Unfortunately, deer on Vancouver Island do not appear to select winter diets on the basis of plant crude protein (Rochelle 1980).

Recently, Nelson et al. (1982, 1984, 1985) have begun to develop relationships between 2,6 diaminopimelic acid (DAPA), a fecal amino acid, and both dietary protein and digestible energy. DAPA may be a better index of diet quality than fecal nitrogen because of its relationship to digestible energy -- especially for deer when lichen (a highly digestible but low protein forage) is present in the diet. Harlow et al. (1975) estimated higher available energy in fall diets of white-tailed deer when a highly digestible but low protein forage item (acorns) was present in their diets. Kie and

Burton (1984) attributed a secondary peak in DAPA levels for Californian black-tailed deer in the month of December to the presence of acorns in the diet.

We proposed to construct DAPA and fecal nitrogen profiles throughout the winter period (November through March) for deer wintering in either old-growth stands or pole-sapling stands, in an attempt to test the hypothesis that there is greater digestible energy available in the old-growth stands because of lichens. An underlying assumption in this sampling scheme was that deer densities in the different stands were not great enough to cause density-dependent effects on diets in the respective habitat types. If the DAPA levels appeared to be different, then diets could be analyzed by fecal fragment analysis stratified by forage class, date, site, and snow depth.

Methods

In the 1st and 3rd weeks of each winter month (November 1985 through March 1986), we collected 15-20 fresh pellet groups in three old-growth winter habitats and two pole-sapling winter habitats in the south Nanaimo River study area. The three old-growth sites (Jump, Dunsmuir, and Sugarloaf) are typical deer winter habitats on Vancouver Island (southerly aspects between 500 and 1000 m in elevation, with Douglas-fir as the dominant tree species). Arboreal lichens are abundant in all three stands.The Dunsmuir pole-sapling site is a 25-year-old Douglas-fir stand on a south aspect between 600 and 800 m in elevation. The Chemainus pole-sapling site is a 20-year-old western hemlock/Douglas-fir stand on a north aspect, about 350 m in elevation. Snow depth in the open was measured adjacent to each site at each collection period. Three pellets from each pellet group were composited for each collection period and site. DAPA and fecal nitrogen were analyzed at the Wildlife Habitat Laboratory, Washington State University. In addition to the regular composite samples, individual pellet groups collected from one old-growth and one pole-sapling site during the February snow period were sent for analysis. This was done to determine variability within a site and also as a check of the composite sample.

Results

The winter of 1985/86 was relatively mild (Section 2), with only two collections made in the snow (November 26 and February 21). Time constraints and other duties meant that only three of the five sites were sampled on February 21, with the other two sites sampled on February 24. Because of the rain and mild conditions from February 21-24, the two collections were not comparable.

The fluctuations of DAPA and fecal nitrogen were inconsistent with respect to snow accumulations (Figure A5.1). In the November 26 collection (with approximately 19 cm of snow in the open), all DAPA and fecal nitrogen values were lower than those in the previous collection (November 5) and, in all but one case, (Dunsmuir pole-sapling) also lower than those in the following collection (December 11). The November 26 period is very close to the peak of the rut for deer on Vancouver Island (Thomas 1970), which may have affected forage intake and quality. In the other snow period (February 21) the fecal nitrogen values in the three sites collected (Jump and Sugarloaf old-growth, and Chemainus pole-sapling) were lower than the pre- and post-collections (February 4 and March 10) in two of the three cases. Even though February 21 had the highest snow accumulation, the fecal nitrogen values were not the lowest for the winter period in any of the three sites. DAPA values for February 21 were lower than the pre- and post-collections in only one site (Jump) and were the lowest values for the winter in only one site (Jump) as well.

Youds et al. (1985) found that DAPA values mirrored fecal nitrogen values for elk on Vancouver Island. Analysis of of this study's individual pellet groups for DAPA and fecal nitrogen for the February 21 collection resulted in a correlation ($r^2$) of .81 (n=32) for the two sets of values. This relationship is not as strong for the composite samples, $r^2$=.46 (n=54), from the entire winter period.

Comparison of values determined by the composite sample versus the means of individual pellet groups is shown in Table A5.1. Composite fecal nitrogen values for the old-growth timber appear to be different than those from the pole-sapling stands (using the recommended 3% standard deviation; B. Davitt,

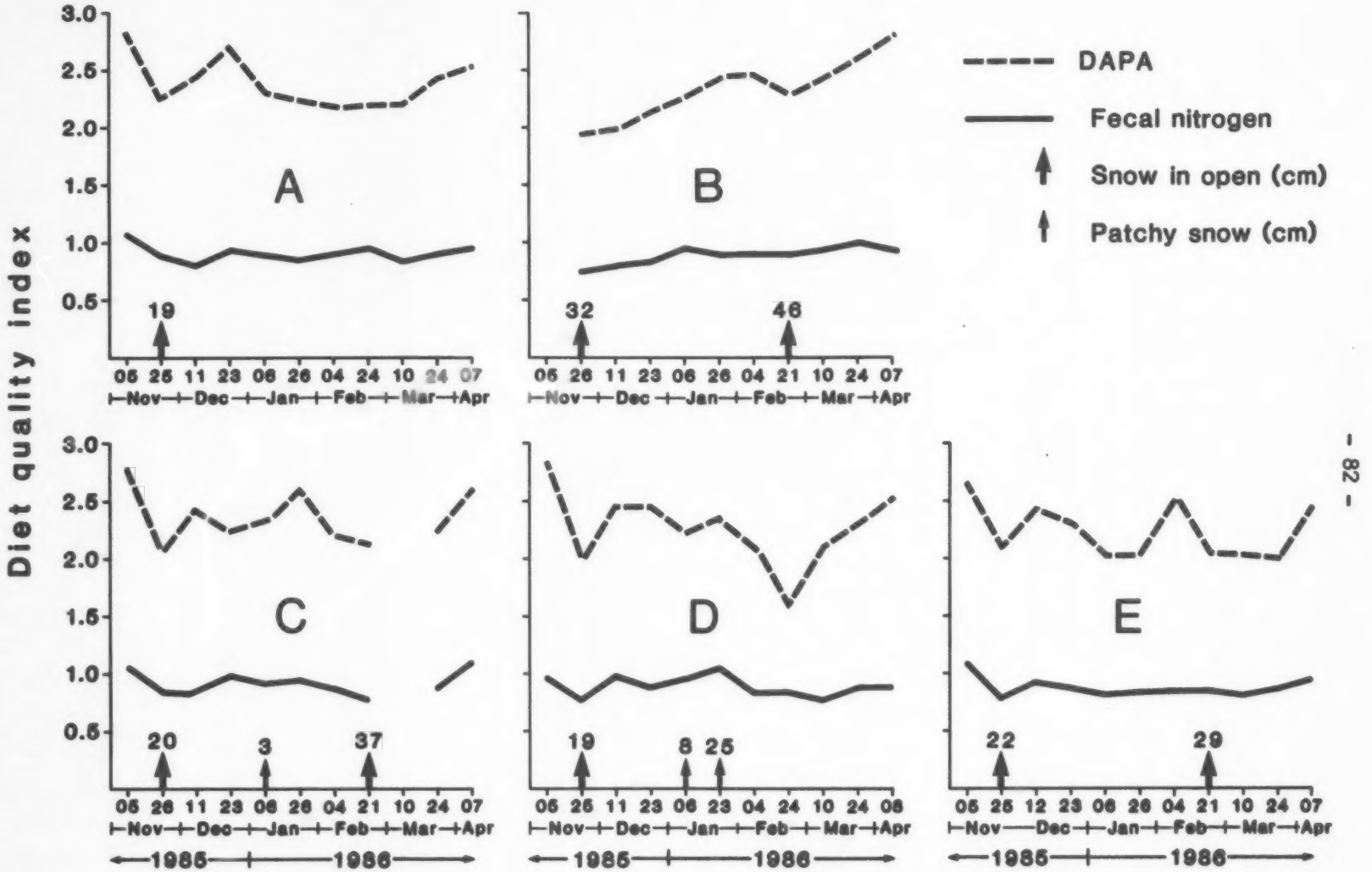


FIGURE A5.1. Diet quality profiles (where A and B are data from two independent pole-sapling stands and C through E are data from three independent old-growth stands.

pers. comm., August 1986), yet the means of the individual pellet groups (using the measured standard deviation) from both habitat types were not statistically different. DAPA values follow a similar pattern, with the composite sample being different (standard deviation 2%; B. Davitt, pers. comm., August 1986) between habitats, while the means of the individual samples were not.

TABLE A5.1. A comparison of DAPA and fecal N values from composite and individual pellet group samples collected in old-growth and pole-sapling winter ranges

| Site | Composite sample | Single pellet groups means (n) | Standard deviation |
|---|---|---|---|
| Old-growth | | | |
| fecal N | 2.12 | 2.03 (18) | .31 |
| DAPA | .77 | .77 (18) | .11 |
| Pole-sapling | | | |
| fecal N | 2.30 | 2.14 (16) | .22 |
| DAPA | 99 | .81 (16) | .09 |

Discussion

A more consistent snowpack throughout the winter may have generated more consistent results. Although we assumed that during snow accumulation diets were more restricted (Appendix 4) and probably lower in quality, that was not reflected in fecal nitrogen or DAPA values, as the lowest values were reached during snow-free periods. Also, the fact that lichens were available to deer only in the old-growth stands did not appear to affect DAPA levels significantly, even though the lichen is highly digestible (Rochelle 1980).

The variability of individual samples within a site casts doubt on the validity of using a composite sample for deer on Vancouver Island. DAPA and fecal nitrogen may reflect seasonal trends in diet quality, but do not appear to be sensitive enough to reflect changes in diet quality between sites for deer on Vancouver Island during winter.

LITERATURE CITED

Cowan, I.M. 1945. The ecological relationships of the food of the Columbian black-tailed deer, Odocoileus hemionus columbianus (Richardson), in the coast forest region of southern Vancouver Island, British Columbia. Ecol. Monogr. 15(2): 111-139.

Gates, B.R. 1968. Deer food production in certain seral stages of the coast forest. M.Sc. thesis. Univ. B.C., Vancouver, B.C. 105 p.

Harlow, R.F., J.B. Whelan, H.S. Crawford, and J.E. Skeen. 1975. Deer foods during years of oak mast abundance and scarcity. J. Wildl. Manage. 39(2): 330-336.

Hebert, D.M. 1973. Altitudinal migration as a factor in the nutrition of bighorn sheep. Ph.D. thesis. Univ. B.C., Vancouver, B.C. 357 p.

Hobbs, N.T. 1987. Fecal indices to dietary quality: A critique. J. Wild. Manage. 51(2):317-320.

Janz,D. 1983. Seasonal composition and quality of Roosevelt elk diets on Vancouver Island. M.Sc. Pap., Univ. B.C., Vancouver, B.C. 68 p.

Jones, G.W. 1975. Aspects of the winter ecology of black-tailed deer (Odocoileu hemionus columbianus (Richardson)) on northern Vancouver Island. M.Sc. thesis. Univ. B.C., Vancouver, B.C. 78 p.

Kie, J.G. and T.S. Burton. 1984. Dietary quality, fecal nitrogen and 2,6 diaminopimellic acid in black-tailed deer in northern California. Res. Note PSW - 364. U.S. Dep. Agric. For. Serv., Pac. Southwest For. Range Exp. Stn., Berkley, Calif. 3 p.

Leslie, D.M. and E.E. Starkey. 1985. Fecal indices to dietary quality of cervids in old-growth forests. J. Wildl. Manage. 49(1): 142-146.

_____. 1987. Fecal indices to dietary quality: A reply. J. Wildl. Manage. 51(2):321-325.

Nelson, J.R., R.C. Chapman, and B.B. Davitt. 1984. FY 1984 progress report for the North American Cooperative Dapa Research and Development Project. Wash. State Univ., Spokane, Wash. 20 p.

Nelson, J.R., R.C. Chapman, B.B. Davitt, and K.A. Blatner. 1985. FY 1985 progress report for the North American Cooperative Dapa Research and Development Project. Wash. State Univ., Spokane, Wash. 22 p.

Nelson, J.R., R.M. Koes, W.H. Miller, and B.B. Davitt. 1982. Big game habitat management on a nutritional basis - a new approach. Proc. Western Elk Workshop Flagstaff, Ariz., pp. 157-166.

Rochelle, J.A. 1980. Mature forests, litterfall, and patterns of forage equality as factors in the nutrition of black-tailed deer on Vancourver Island. Ph.D. thesis. Univ. B.C., Vancouver, B.C. 295 p.

Stevenson, S.K. 1978. Distribution and abundance of arboreal lichens and their use as forage by black-tailed deer. M.Sc. thesis. Univ. B.C., Vancouver, B.C. 148 p.

_____. 1985. Enhancing the establishment and growth of arboreal forage lichens in intensively managed forests: problem analysis. B.C. Min. Environ. and Min. For., Research IWIFR - 26. Victoria, B.C. 40 p.

Thomas, D.C. 1970. The ovary, reproduction, and productivity of female columbian black-tailed deer. Ph.D. thesis. Univ. B.C., Vancouver, B.C. 211 p.

Youds, J., K. Brunt, and D. Becker. 1985. Vancouver Island Roosevelt elk/ intensive forestry interaction: progress report 1981-1984. B.C. Min. Environ. and Min. For., Research IWIFR-21. Victoria, B.C. 71 p.

APPENDIX 6. Activity patterns of deer during specific winter weather events

## Introduction

Activity, when sampled simultaneously with location, may help explain patterns of habitat selection. Activity in a habitat may imply that forage is the important feature to the animal, while inactivity may indicate that cover characteristics are what the animal is selecting for.

We first attempted to determine activity budgets by locating a radio-collared deer every 15 minutes. However, one animal (deer No. 74) only moved during crew shift changes when people were temporarily absent, indicating an observer effect on animal movements. This approach was abandoned. In the second attempt, motion-sensing radio transmitters were used. They are reported to have the potential to monitor activity from a remote station continuously, thereby freeing personnel to radio-locate the animals (Garshelis et al. 1982). The objective of this study was to test, in conjunction with our intensive radio telemetry sessions (Section 3), both the use of motion-sensing radio collars and the location and placement of monitoring stations.

## Methods

Motion sensing radio transmitters (Telonics, Inc., Mesa, Ariz.) were placed on selected deer in the study area. Mercury tip-switches in combination with reset sensors changed the pulse of the radio transmitters depending on their orientation and movement. The tip-switch changed the pulse rate of the signal depending on whether the deer was in a head-up or head-down position. The reset sensor changed the signal to a third pulse rate if there was no movement for approximately 10 minutes. The pulse rate and signal amplitude were monitored continuously using a whip antenna, a Telonics Model TR-2 receiver and TDP-2 digital processor, and a Rustrak 2-channel chart recorder. The receiving equipment was housed in a waterproof container and was powered by a 12-volt car battery.

Initially, it was hoped that the data could be categorized by different behaviour types such as feeding, resting, or travelling. However, Gillingham

and Bunnell (1985), in a test of this type of motion sensing collar, found the data revealed at best two simple categories: active and inactive. Paper tapes were analyzed using the methods and criteria in Gillingham and Bunnell (1985).

Results

Problems occurred in various stages of the data collection. Of the six motion-sensing collars placed on animals, only one animal was successfully monitored on more than one occasion. One animal (No. 66) migrated out of the study area for the winter, while another (No. 36) had poor signal strength. The tip-switch malfunctioned in one (No. 32), wolves killed another (No. 34), and one animal used an area of rock bluffs (No. 35) where signal reception was poor. There were four successful 3-day sessions with deer No. 55 in the 1983/84 field season. The first two (April 28-May 1 and October 11-14) were tests of the equipment's performance and location (Fig. A6.1). They showed peaks of activity at dawn and dusk that are characteristic of deer (Dasmann and Taber 1956; Hanley 1982). There was also an apparent avoidance of afternoon heat in the October 11-14 session. A summary of activity periods and mean lengths of those periods is given in Table A6.1. The fewer active periods but longer duration of activity in October compared to April is probably a function of forage quality and quantity, which influences food passage rates (Hanley 1982) and thus overall foraging behaviour.

The winter sessions occurred during intensive-monitoring periods (Section 3). The December 20-22 period was dry and cold (-4 to -14°C, Fig. 6 in Section 2) with a snow level of 700 m, while January 10-12 was the subsequent warm period (3-12°C, Fig. 6 in Section 2) with a snow level of approximately 1000 m. The monitored animal responded to the cold by reducing daily average activity to 41% with no particular pattern of activity bouts (Fig. A6.1). During this period the animal remained active (although in short periods) even in the coldest part of the night and early morning. Similar results were observed by Ozoga and Gysel (1972). When the temperature warmed (January 10-12), the deer increased its daily average activity to 56% through fewer, but longer, active bouts.

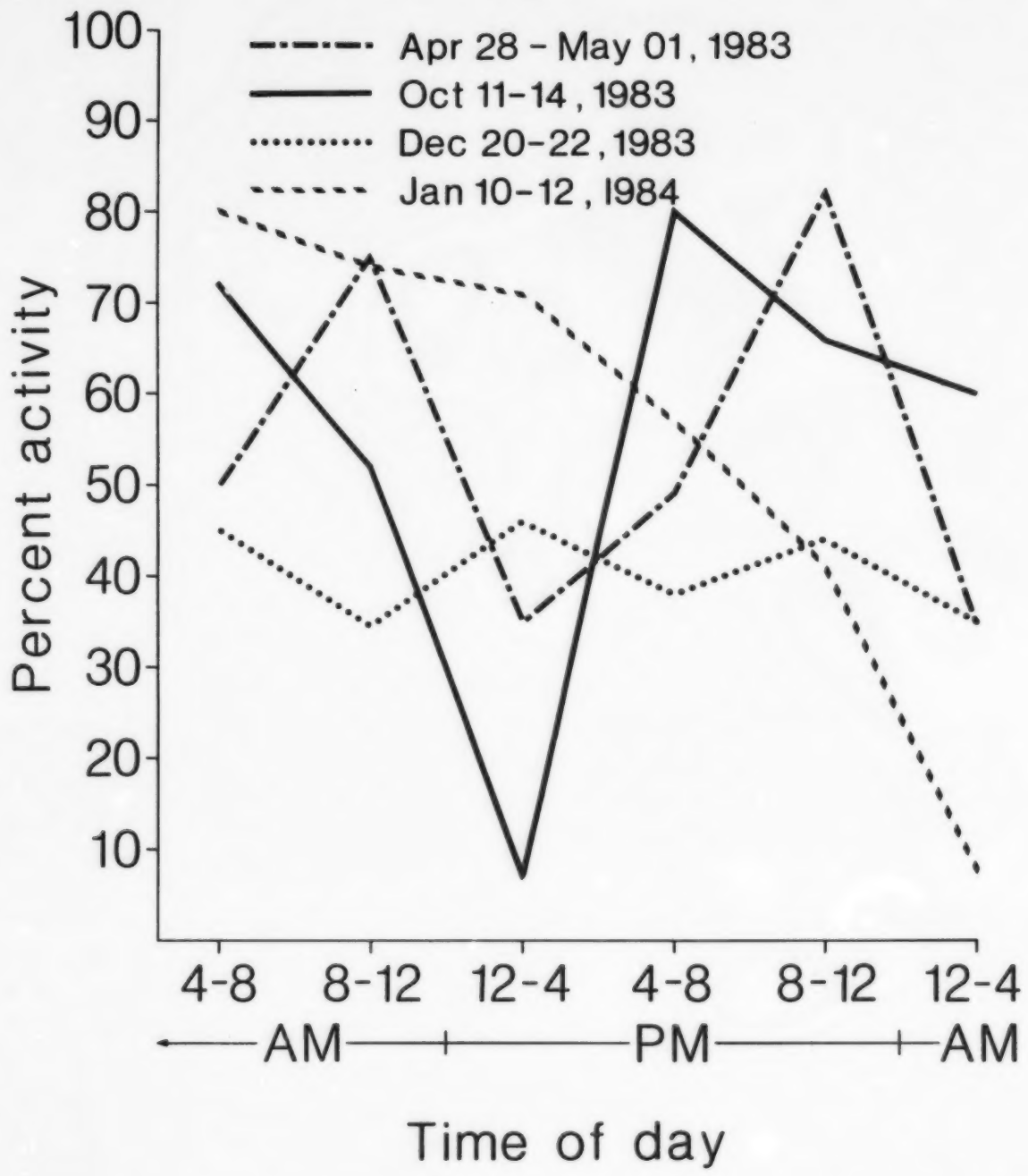


FIGURE A6.1. Activity patterns recorded from four 3-day monitoring sessions on mature female 1550.

TABLE A6.1. Summary of activity from four 3-day monitoring sessions on mature female 1550

| Date | No. active periods | Mean length (min) | Standard deviation | % Activity 3-day |
|---|---|---|---|---|
| April 28-May 1, 83 | 34 | 66 | 52 | 52 |
| October 11-14, 83 | 21 | 113 | 95 | 55 |
| December 20-22, 83[a] | 24 | 77 | 49 | 41 |
| January 10-12, 84[a] | 14 | 144 | 56 | 56 |

[a] Intensive radio-location of this animal also occurred on these dates.

Discussion

Home range data from the intensive monitoring sessions in December 1983 and January 1984 (see periods 3 and 4 respectively; Table 3 in Section 3) showed a consistent trend to smaller home ranges during the colder December session. This trend is consistent with differences in the proportion of time spent in activity by deer No. 55 for the same periods (41 vs. 56%) and indicates a strategy of minimizing energy expenditure during stressful conditions (in this case cold temperatures). Further sampling during deep snow conditions were planned, but snow accumulations in 1985 and 1986 were of short duration (Figure 6 in Section 2) and other phases of winter work took priority.

## LITERATURE CITED

Dasmann, R.F. and R.D. Taber. 1956. Behavior of Columbian black-tailed deer with reference to population ecology. J. Mammal. 37: 143-164.

Garshelis, D.L., H.B. Quigley, C.R. Villarrubia, and M.R. Pelton. 1982. Assessment of telemetric notion sensors for studies of activity. Can. J. Zool. 60:1800-1805.

Gillingham, M. and F. Bunnell. 1985. Reliability of motion sensitive radio collars for estimating activity of black-tailed deer. J. Wildl. Manage. 49(4): 951-958.

Hanley, T. 1982. Cervid activity patterns in relation to foraging constraints: western Washington. Northwest Sci. 56(3): 208-217.

Ozoga, J. and L. Gysel. 1972. Response of white-tailed deer to winter weather. J. Wildl. Manage. 36: 892-896.

Queen's Printer for British Columbia©
Victoria, 1987